sweep oscillator

6400 SERIES

6420 MODEL

88 SERIAL

BWO Tube type: Stewart ☐ Varian ☐
Leveling capability: Int-Ext ☐ Ext only ☒

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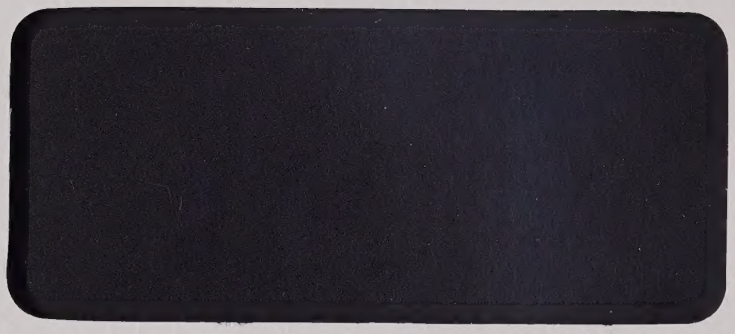

INSTRUCTION MANUAL

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BWO Tube type: Stewart ☐ Varian ☐
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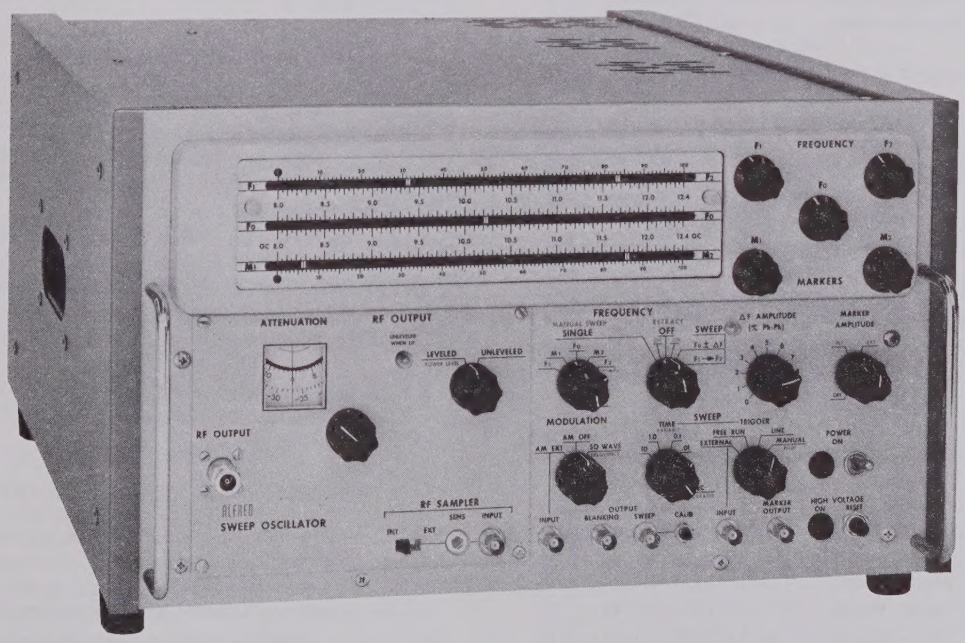

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SECTION 1

GENERAL INFORMATION

1.1 THE MODEL 6400 SERIES SWEEP OSCILLATOR.

The Model 6400 Series single-band Sweep Oscillators cover the frequency range 1 - 40 GHz. The Model 6400 instrument covered by this manual and its frequency range and leveling mode are entered on the title page. The swept frequency output is a linear function of time, and both sweep width and sweep rate can be independently adjusted over a wide range. In addition to its swept rf output, the instrument can supply stable single-frequency signals, tunable anywhere in its frequency range, with stability rivaling that of mechanically-tuned signal generators.

The instrument contains a linearly calibrated frequency dial for simple, fast selection of swept ranges or individual frequencies. For versatility, the instrument offers three sweep modes, three markers, five adjustable frequencies, internal and external modulation and leveling capabilities, display outputs, and other features.

The instrument provides two electronically controlled automatic sweeps (broadband and narrow-band symmetrical sweep), and manual sweep modes. The broadband sweep covers all or any portion of the full frequency range from 100% to 2%. During narrow-band symmetrical sweep operation, the frequency can be swept up to ± 5% of the full frequency range, about any desired center point. These sweeps can be triggered automatically in a free-running mode or from the line. An external trigger source or manual triggering also can be used. Sweep time can be adjusted over a range of 0.01 to 100 seconds for any swept frequency limits. During manual sweep, the frequency can be manually swept over the full range of the instrument or between preset start and stop frequencies.

Frequency markers are available in all the sweep modes. Three rf modulated frequency markers are provided during leveled operation. They appear as rf absorption at the frequencies selected by the marker controls. If markers are needed when the rf power is unleveled, video pulse markers are available at the MARKER OUTPUT connector for combination with the rf detector output display.

Several voltages are available for oscilloscope and recorder control. For X-axis deflection of oscilloscopes and recorders a +15 V sweep voltage coincident with the rf sweep is available. A +50 V blanking signal is available during retrace. Also during retrace, at sweep speeds slower than 1 second, a relay with isolated S.P.D.T. contacts is available to operate a recorder pen lift. The rf output may be either left on or turned off automatically during retrace.

The rf output may be amplitude modulated by either an external signal or an internally generated square wave. The square wave frequency is continuously adjustable from 800 to 1200 Hz. Provision is made to permit externally controlled frequency modulation of the rf output. The rf output may be leveled across all or any portion of the band. The method of leveling and the provision of an internal leveling sampler depends upon the Model used. See Section 1.2 below.

General Specifications of the Model 6400 Series Sweep Oscillators are given in Table 1-1. The microwave source used is a backward wave oscillator (BWO) tube, which is encapsulated for protection and easily replaced. Protective circuits reduce the likelihood of damage to the tube. An internal time meter indicates hours of microwave tube operation.

1.2 DESCRIPTION OF 6400 SERIES MODEL NUMBERS.

In the 6400 Series model-numbering scheme, the third digit denotes frequency band (see Table 1-2) and the last digit denotes leveling/power control provisions. An asterisk (*) is substituted for the third digit in this manual when describing power control features of model number "families" of units in several frequency bands which have the same last digit. The Model 6400 Series is divided into six groups: the Model 64(*)0 Series, the Model 64(*)1 Series, the Model 64(*)2 Series, the Model 64(*)3 Series, the Model 64(*)4 Series, and the Model 64(*)5 Series. These series differ in the type of rf leveling and power control arrangements provided, as described below. Specifications and tube data for individual Model 6400 Series instruments are given in Table 1-2. For added clarity in Table 1-2, an "E" is used to identify models requiring external leveling; an "I" is used to identify models having internal leveling; and an "A" is used to identify models having internal leveling plus a sampler-attenuator for 50 db power control range. The leveling and power control configurations denoted by each fourth digit are as follows:

1.2.1 THE MODEL 64(*)0 SERIES INSTRUMENTS. The Model 64(*)0 Series instruments provide an unleveled rf signal and cover the frequency range from 1 GHz to 40 GHz. They contain a leveler amplifier but do not contain an rf sampler component. Thus, the rf output can be leveled with an external sampler connected to the rf sampler input jack to drive the leveler amplifier. In this Series, the leveling signal is coupled to the grid of the BWO tube and the units are therefore designated as "grid leveled" type units. All modes of operation may be used in both the leveled and unleveled conditions. In the units operating below 12.4 GHz, the rf power output can be varied during leveled operation only. Above 12.4 GHz, a flap attenuator allows the power to be varied during unleveled operation also.

1.2.2 THE MODEL 64(*)1 SERIES INSTRUMENTS. The Model 64(*)1 Series instruments provide either a leveled or unleveled rf signal and cover the frequency range from 1 GHz to 18 GHz. They contain a leveler-amplifier and an internal rf sampling component. The leveler signal is coupled to the grid of the BWO tube so that these units are also designated as "grid leveled" type units. This Series also allows use of an external sampling component to level the rf signal at the load. A front panel switch selects either internal or external sampling. All modes of operation can be used in both the leveled and unleveled conditions. The output power can be varied during leveled operation only.

1.2.3 THE MODEL 64(*)2 SERIES INSTRUMENTS. The Model 64(*)2 Series instruments provide an unleveled rf signal and cover the frequency range from 1 to 12.4 GHz. They contain a leveler amplifier but do not contain an rf sampler component. Thus, the rf output can be leveled with an external sampler connected to the rf sampler input jack to drive the leveler amplifier. In this Series, the leveling signal

is coupled to a PIN diode attenuator which provides the leveling. Hence, these units are designated as "PIN diode leveled" or "solid state leveled" type units. All modes of operation can be used in both the leveled and unleveled conditions, and the output power can be varied in both conditions.

1.2.4 THE MODEL 64(*)3 SERIES INSTRUMENTS. The Model 64(*)3 Series instruments provide either a leveled or unleveled rf signal and cover the frequency range from 1 GHz to 12.4 GHz. They contain a leveler-amplifier and an internal rf sampling component. In this Series, the leveling signal is coupled to a PIN diode attenuator which provides the leveling. Hence, these units are designated as "PIN diode leveled" or "solid state leveled" type units. This Series also allows use of an external sampling component to level the rf signal at the load. A front panel switch selects either internal or external sampling. All modes of operation can be used in both the leveled and unleveled conditions, and the output power can be varied in both conditions.

1.2.5 THE MODEL 64(*)4 SERIES INSTRUMENTS. The Model 64(*)4 Series instruments provide either a leveled or unleveled rf signal and cover the frequency range from 1 to 8 GHz. They contain a leveler-amplifier and an internal rf sampler-attenuator that permits adjustment of the rf power output level over a 50 db range in either the leveled or unleveled operating modes. In this Series, the leveling signal is coupled to the grid of the BWO tube, and these units are designated as "grid leveled" type units. This Series also allows use of an external sampling component to level the rf signal at the load, with power level control still provided by the internal attenuator. A front panel switch selects either internal or external sampling. All modes of operation can be used in both the leveled and unleveled conditions.

1.2.6 THE MODEL 64(*)5 SERIES INSTRUMENTS. The Model 64(*)5 Series instruments provide either a leveled or unleveled rf signal and cover the frequency range from 1 GHz to 8 GHz. They contain a leveler-amplifier and an internal rf sampler-attenuator that permits adjustment of the power output level over a 50 db range in either the leveled or unleveled operating modes. In this Series, the leveling signal is coupled to a PIN diode attenuator which provides the leveling, and these units are designated as "PIN diode leveled" or "solid state leveled" type units. This Series also allows use of an external sampling component to level the rf signal at the load, with power level control still provided by the internal attenuator. A front panel switch selects either internal or external sampling. All modes of operation can be used in both the leveled and unleveled conditions.

1.3 SCOPE OF THE MODEL 6400 SERIES INSTRUCTION MANUAL.

This Instruction Manual provides detailed descriptive data, operating instructions, circuit theory, and servicing information for the Model 6400 instrument, and general information covering applications. The manual shipped with each instrument includes the rf output test data sheet for the instrument.

1.4 APPLICATIONS OF THE MODEL 6400 SERIES.

By offering both swept-frequency and stable fixed-frequency output, with many modulation and control options, the Model 6400 Series instruments can fulfill practically any requirement for microwave signal generation. They can be used to drive advanced swept-frequency test setups or for precision single-frequency tests. They can be amplitude-modulated, pulse-modulated, frequency-modulated, and remote-programmed to meet special systems requirements. Detailed operating instructions for use of the instrument in its various operating modes are given in Section 3. Advanced swept-frequency measurement techniques using the ALFRED Model 8000/7051 and 8000/7052 Sweep Analyzers for readout are described in ALFRED Application Note 101 and other applications literature available from either the factory or your ALFRED representative. If you need information regarding special applications, contact the factory or your ALFRED representative.

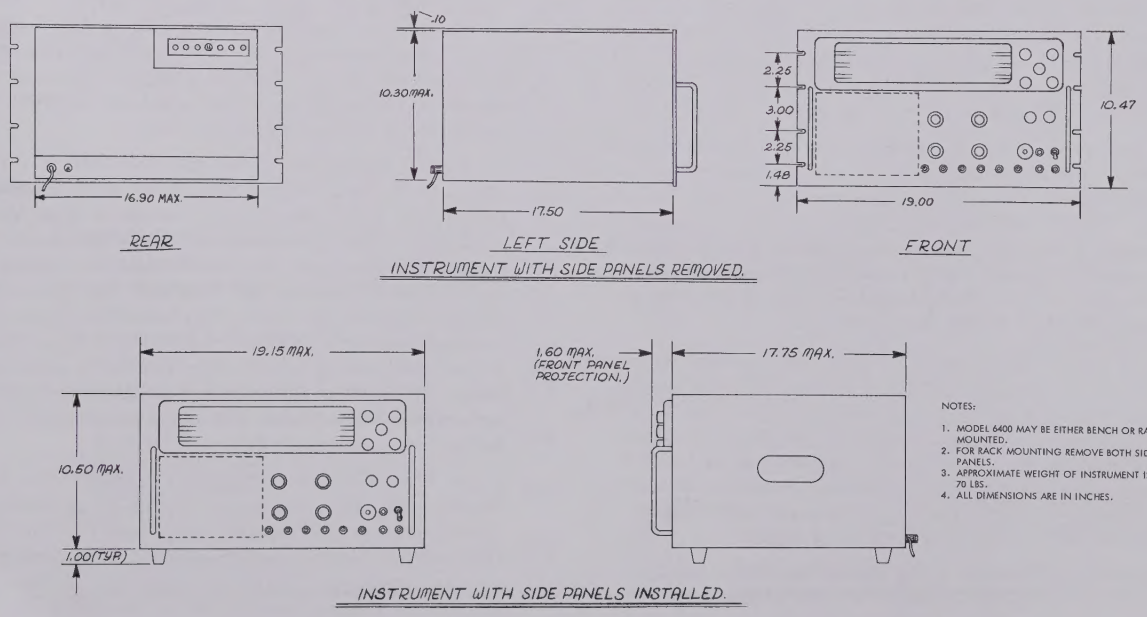


Figure 1-1. Model 6400 Installation Drawing

Table 1-1. Specifications of Model 6400 Series Sweep Oscillators

POWER LEVEL CONTROL: 64(*)0 Series (through 12.4 GHz) and 64(*)1 Series (through 18 GHz) are grid controlled, having power control > 5 db available during leveled operation only. 64(*)0 Series (above 12.4 GHz) has power control > 5 db during both leveled and unleveled operation. 64(*)2 and 64(*)3 Series are PIN diode controlled, providing power control > 5 db during leveled and unleveled operation. 64(*)4 and 64(*)5 Series include an internal precision attenuator to provide a power control range > 50 db in leveled and unleveled operation. 64(*)4 Series is grid-controlled. 64(*)5 Series is PIN diode controlled.

POWER VARIATION: 64(*)1, 64(*)3, 64(*)4, and 64(*)5 Series internally leveled: see table (page 3). All units externally leveled: 0.1 db plus rf sampler (directional coupler and crystal detector) variation. All units unleveled: less than 10 db across entire band.

BROADBAND SWEEP: Start Sweep (F_1) and End Sweep (F_2), set with independent controls. Width continuously adjustable from 2% to 100% of range.

SYMMETRICAL SWEEP: Center frequency (F_0) and Deviation (ΔF Amplitude) set with controls completely independent of those used for broadband sweep. Width continuously adjustable from 0 to 10% of range anywhere in band, with calibrated ΔF control.

SWEEP TIME: Continuously adjustable. 10 milliseconds to 100 seconds per sweep in four ranges. Panel sweep light energized during sweep.

SWEEP TRIGGER: External; Free Running; Line; Manual (single sweep). External trigger of 5 volts minimum for duration of 10 microseconds minimum actuates sweep. Line trigger synchronizes sweep with line frequency.

MANUAL SWEEP: The manual sweep control varies the frequency between the frequencies set with F_1 and F_2. Single-frequency controls may also be swept manually.

SINGLE FREQUENCY: Five single frequencies may be preset anywhere in the band (with F_0, F_1, F_2, M_1 and M_2 controls) and selected with a panel switch.

SWEEP OUTPUT: 0 to 15 volts sawtooth. On $F_1 \rightarrow F_2$ swept operation, sawtooth wave begins at F_1 (0 volts) and increases linearly to F_2 (15 volts) regardless of frequency setting. During single frequency operation or manual sweep controlled by F_0, M_1, or M_2, a 0 to 15-volt signal proportional to frequency is provided. At single-frequency F_1, signal out is always zero volts and at F_2, signal out is always +15 volts. During $F_1 \rightarrow F_2$ manual sweep the sweep output varies linearly from 0 to 15 volts as the frequency is varied from F_1 to F_2 regardless of frequency band selected. Output impedance is 10 K ohms.

BLANKING OUTPUT AND PEN LIFT: A + 50 volt signal is available during sweep retrace. Output impedance, 10 K ohms. Pen lift relay closure (open or closed contacts available) during sweep retrace on two slowest sweep ranges. Terminals on rear chassis.

REMOTE FREQUENCY AND POWER CONTROL: For stepwise or continuous control of frequency or power, 1000 ohm voltage dividers or potentiometers may be connected to rear of instrument. A separate rear connector permits remote frequency programming with a 0 to 15 V signal; input impedance 15 K ohms.

RF RETRACE ON - OFF: Panel switch controls whether rf signal is on or completely off during retrace.

FREQUENCY MARKERS: M_1, M_2 and F_0. Available either as pip in rf signal or as video pulse on panel BNC connector. Frequency continuously adjustable. Marker amplitude continuously adjustable to 0, width varies with amplitude from 0 to 0.05% of frequency range.

VIDEO FREQUENCY MARKERS: Negative video marker pulses having amplitude adjustable up to 1 volt are available from a BNC connector on the front panel. The source impedance is approximately 1000 ohms.

FREQUENCY STABILITY: Better than 0.01% per degree centigrade.

FREQUENCY AND MARKER CALIBRATION: 64(*)2, 64(*)3, 64(*)5 Series better than 1% under all operating conditions. 64(*)0, 64(*)1, and 64(*)4 Series better than 1% during unleveled operation.

AMPLITUDE MODULATION: Rise and fall response times of the 64(*)0, 64(*)1, and 64(*)4 Series are $\approx$ 1 µsec during unleveled operation and 20 µsec or less during leveled operation, with a 10 volt signal for full on-off control. The peak power level will correspond to maximum power available in the unleveled mode and to the power level set by the rf level control in the leveled mode.

Rise and fall response times of the 64(*)2, 64(*)3, and 64(*)5 Series are $\approx$ 1 µsec during unleveled operation and 10 µsec or less during leveled operation, with a 10 volt signal for full on-off control. The peak power level will correspond to the setting of the rf level control.

With a pulse source impedance of 50 ohms or less, rise and fall response times of $\approx$ 0.1 µsec are obtained during unleveled operation. A pulse amplitude of typically +45 volts is required in all models listed covering the ranges up to 4 GHz; above 4 GHz, a pulse amplitude of typically +100 volts is required.

Internal square wave, adjustable 800 to 1200 Hz. Amplitude 64(*)0 and 64(*)1 Series 1 through 12.4 GHz unleveled, 0 to full on; 64(*)0 Series 12.4 GHz to 40 GHz, all other series, and all leveled units, 0 to power set with panel controls. Rise and fall time leveled less than 20 µsec, unleveled $\approx$ 1 µsec.

FREQUENCY MODULATION: Externally applied signal of 15 volts peak-to-peak provides deviation over full frequency range. Positive-going voltage increases frequency. Fm can be applied during any mode of operation. The response extends from dc to 100 Hz for full-band sweep and to beyond 10 KHz at reduced sweep width. Input impedance, 15 K ohms.

SPURIOUS SIGNALS: Non-harmonics 40 db, harmonics 20 db below rated power output.

LEVELER INPUT: -60 mv minimum required for optimum performance at rated rf output for external leveling. 2.5 K ohms input impedance.

CONNECTORS: Type N Female except for waveguide bands as follows: 8 to 12.4 GHz, UG135/U; 10 to 15.5 GHz, WR75; 12.4 to 18 GHz, UG419/U; 18 to 26.5 GHz, UG595/U; and 26.5 to 40 GHz, UG599/U flanges.

POWER INPUT: 105 to 125 volts, or 210 to 250 volts, 50/400 Hz. Approximately 150 volt-amperes.

PHYSICAL: Removable cabinet sides permit installation in standard 19" rack. Height 10 1/2 inches, width 19 inches, depth behind panel 17 1/2 inches, total depth 19 inches. Light gray panel, contrasting sides. Weight approximately 70 pounds.

Refer to the installation outline drawing, Figure 1-1.

Table 1-2. Specifications of Individual 6400 Series Models

Frequency GHz	Sampling Method (see Para. 1.2)*	Grid Leveled				PIN Diode Leveled			
		Model	Rated Power Output (mw)	Power Variation (leveled db)	Maximum Residual fm (KHz - pk)	Model	Rated Power Output (mw)	Power Variation (leveled db)	Maximum Residual fm (KHz - pk)
1 to 2	E	6410	80	—	30	6412	60	—	30
	I	6411	70	±0.3	30	6413	60	±0.3	30
	A	6414	20	±0.5†	30	6415	15	±0.5†	30
1.4 to 2.5	E	6410-1	80	—	30	6412-1	60	—	30
	I	6411-1	70	±0.3	30	6413-1	60	±0.3	30
	A	6414-1	20	±0.5†	30	6415-1	15	±0.5†	30
2 to 4	E	6420	60	—	30	6422	40	—	30
	I	6421	50	±0.3	30	6423	40	±0.3	30
	A	6424	15	±0.5†	30	6425	10	±0.5†	30
1.7 to 4.2	E	6420-1	35	—	30	6422-1	15	—	30
	I	6421-1	30	±0.5	30	6423-1	15	±0.5	30
4 to 8	E	6430	30	—	50	6432	15	—	50
	I	6431	25	±0.5	50	6433	15	±0.5	50
	A	6434	5	±0.5†	50	6435	5	±0.5†	50
3.5 to 6.75	E	6430-1	40	—	50	6432-1	20	—	50
	I	6431-1	30	±0.4	50	6433-1	20	±0.4	50
	A	6434-1	5	±0.5†	50	6435-1	5	±0.5†	50
3.7 to 8.3	E	6430-2	10	—	50	6432-2	5	—	50
	I	6431-2	10	±0.5	50	6433-2	5	±0.5	50
7 to 11	E	6440	20	—	75	6442	10	—	50
	I	6441	15	±0.5	75	6443	10	±0.5	50
7 to 12.4	E	6440-1	20	—	75	6442-1	10	—	50
	I	6441-1	15	±0.75	75	6443-1	10	±0.75	50
8 to 12.4	E	6450	60	—	75	6452	20	—	50
	I	6451	50	±0.5††	75	6453	20	±0.5††	50
10 to 15.5	E	6460	35	—	150				
12.4 to 18	E	6470	40	—	150				
	I	6471	25	±0.8	150				
18 to 26.5	E	6480	10	—	200				
26.5 to 40	E	6490	5	—	350				

†Over power control range of 20 db from maximum power level. ††8.2 - 12.4 GHz; ±0.7 for 8.0 - 12.4 GHz.

*An "E" is used to identify models requiring external leveling; an "I" is used to identify models having internal leveling; and an "A" is used to identify models having internal leveling plus a sampler-attenuator for 50 db power control range.

SECTION 2
INITIAL INSTRUCTIONS

2.1 RECEIVING INSPECTION.

Upon receiving your Model 6400, carefully unpack the instrument and check for shipment damage. If some damage is evident, file a claim against the carrier. Refer to the Shipment Damage Claim form in the back of this manual.

CAUTION

THIS INSTRUMENT CONTAINS A MICROWAVE TUBE WHICH IS EXTREMELY SENSITIVE TO FERROUS MATERIAL. USE ONLY NON-MAGNETIC SCREWDRIVERS AND OTHER TOOLS WHEN WORKING NEAR THE BWO TUBE, AND REMOVE YOUR WRIST WATCH TO AVOID MAGENTIC DAMAGE TO IT.

2.2 POWER REQUIREMENTS.

The unit is normally connected at the factory for operation at 105 to 125 V ac (115 V ac nominal) and 50 to 400 Hz. However, provisions are provided for easy conversion to operation at 210 to 250 V ac (230 V ac nominal). With the top cover removed, locate the power switch labeled 115 VAC (Figure 5-1). Remove the plate and move the switch forward to its alternate position. Turn the plate over and replace it with 230 VAC showing. To reconvert for 115 V ac operation, reverse the above procedure.

CAUTION

TO PROVIDE PROPER PROTECTION TO THE INSTRUMENT, FUSES MUST BE CHANGED WHENEVER POWER CONVERSION IS MADE, IN ACCORDANCE WITH THE FOLLOWING TABLE:

FUSE	VALUE FOR 115 VAC OPERATION	VALUE FOR 230 VAC OPERATION
F_1	1.2 AMP (Slo Blo)	0.6 AMP (Slo Blo)
F_2	3 AMP (Slo Blo)	1.5 AMP (Slo Blo)
F_3	2 AMP (Slo Blo)	1 AMP (Slo Blo)

2.3 CHASSIS GROUNDING.

The instrument is supplied with a three-conductor power cord and a three-prong plug, which grounds the instrument when plugged into an appropriate receptacle. If a three-prong to two-prong adapter is used, make sure the unit is properly connected to ground by grounding the adapter pigtail lead.

WARNING

FAILURE TO PROPERLY GROUND THE INSTRUMENT CAN DEGRADE ITS PERFORMANCE AND STABILITY, AND COULD ALLOW AN ABOVE-GROUND POTENTIAL TO BUILD UP ON THE CHASSIS, WHICH COULD BE DANGEROUS TO OPERATING PERSONNEL.

2.4 COOLING.

Adequate space must be provided at the top, rear and bottom of the unit for cooling purposes. Although the Model 6400 Series oscillator instruments do not require forced air cooling, due to use of all-solid-state components in most circuits, proper ventilation for convection cooling is required, with one inch at the top and one-half inch at the bottom.

2.5 INCOMING INSPECTION TEST.

CAUTION

MANY INTERNAL ADJUSTMENTS LOCATED WITHIN THE MODEL 6400 CHASSIS ARE CRITICAL. THEY HAVE BEEN CAREFULLY FACTORY-ADJUSTED PRIOR TO SHIPMENT AND SHOULD NOT NEED FIELD ADJUSTMENT. BECAUSE OF THE INTERACTION OF THESE ADJUSTMENTS A COMPLETE REALIGNMENT MAY BE REQUIRED IF THEY ARE DISTRUBED. REFER TO SECTION 5 OF THIS MANUAL BEFORE TOUCHING ANY ADJUSTMENTS.

The following inspection test may be performed prior to regular operation of the Model 6400. In each step, leave switch settings as made previously unless instructed otherwise.

2.5.1 FREQUENCY CHECK.

a. Make the following panel control settings:
   FREQUENCY Mode Selector to SINGLE
   SINGLE Frequency Selector to F_0
   MODULATION Selector to AM OFF
   RF OUTPUT switch to UNLEVELED
   POWER LEVEL control to MAXIMUM clockwise position
   F_0 FREQUENCY indicator to the low-end frequency on the dial
   Turn POWER switch to ON.

   NOTE: A time delay relay delays application of high voltage for approximately 60 seconds after the power switch is turned on. This is to allow a brief warm-up period for the microwave oscillator tube filament. If the ac power is off for even an instant, the normal 60-second delay will occur before the high voltage returns after turn-on.

b. Connect the RF OUTPUT connector through a suitable frequency meter and attenuator pads to a video detector. Connect the detector output to the vertical channel of an oscilloscope. Set the scope for self-triggering.

CAUTION

THE RF POWER OUTPUT CAN BE AS GREAT AS 300 MW. DO NOT EXCEED THE MAXIMUM POWER RATING OF THE DETECTOR. SUITABLE PADS SHOULD BE USED TO REDUCE THE OUTPUT POWER AND THUS PROTECT THE DETECTOR.

c. Check the frequency by observing the drop of the scope trace as the frequency meter is moved through the output frequency. Repeat the check using several F_0 settings across the band. The reading on the frequency meter should be within 1% of the frequency indicated on the dial. If not, refer to Section 5 for recalibration.

2.5.2 SWEEP VOLTAGE CHECK.

a. Make the following panel control settings:
FREQUENCY Mode Selector to SWEEP; $F_1 \rightarrow F_2$
SWEEP TIME to 0.01 seconds; and concentric VARIABLE Control fully clockwise (CAL position).
SWEEP TRIGGER Selector to LINE.

b. Connect an oscilloscope to the SWEEP OUTPUT jack using dc coupling. The signal observed should be a sawtooth with an amplitude of exactly 15 volts peak-to-peak.

2.5.3 RF OUTPUT CHECK.

a. Make the following panel control settings:
F_1 FREQUENCY indicator to 0 (low end of scale).
F_2 FREQUENCY indicator to 100 (high end of scale).
FREQUENCY RETRACE to OFF.

b. Connect a video detector to the RF OUTPUT connector using suitable pads, as in 2.5.1, and connect the detector output to the vertical channel of an oscilloscope.

c. Connect the SWEEP OUTPUT jack to the horizontal deflection channel of the oscilloscope.

d. Visually check the unleveled rf output across the band.

2.5.4 LEVELER CHECK IN MODEL 64(*)1, 64(*)3, 64(*)4, or 64(*)5. (For other units, skip to 2.5.5.)

a. Set the RF OUTPUT switch to LEVELED, and the RF SAMPLER switch to INTERNAL.

b. Observe the rf output with an oscilloscope connected as in 2.5.3.

c. Rotate the POWER LEVEL control counterclockwise until the rf output is leveled, at which time the UNLEVELED light will go out.

d. Visually check the leveled rf output across the band.

2.5.5 MODULATION CHECK.

a. Make the following panel control settings:
MODULATION Selector to SQ WAVE

b. Observe the rf output with an oscilloscope connected as in 2.5.3. The display should be keyed on and off in a symmetrical square wave pattern.

2.5.6 TRIGGER CHECK.

a. Turn the TRIGGER Selector switch to FREE RUN.

b. Observe the output with an oscilloscope connected as in 2.5.3. The automatic sweep should continue.

c. Turn the TRIGGER Selector switch to MANUAL.

d. Press the button in the TRIGGER Selector switch. One sweep should be obtained after each push of the button.

2.6 RETURNING THE INSTRUMENT.

If it becomes necessary to return the instrument to ALFRED ELECTRONICS, autorization must first be obtained from our Sales Department.

When authorization is received, prepare the instrument for shipment. A protective shipping plate or a piece of cardboard should be placed over the dial plate area for portection. A board or heavy cardboard buffer should be placed in front of the unit across the handles to protect the panel from blows against the container.

The instrument should be wrapped in a protective material such as polyethylene and heavy wrapping paper to protect against marring by the padding used in the container. A sufficient quantity of padding material, such as hair flex, should be placed all around the instrument for cushioning. If the original shipping container is not available, an equivalent rugged cardboard container or wooden crate should be used for the packing carton. Pack the instrument so that it cannot move around in the container. A letter containing all pertinent information should be included in the package, unless such a letter has previously been sent to our Sales Department.

SECTION 3 – OPERATION

3.1 FRONT PANEL CONTROLS (See Figure 3-1).

A functional description of all front panel controls is given in Table 3-1. In the table, CW and CCW are used to abbreviate clockwise and counterclockwise, respectively.

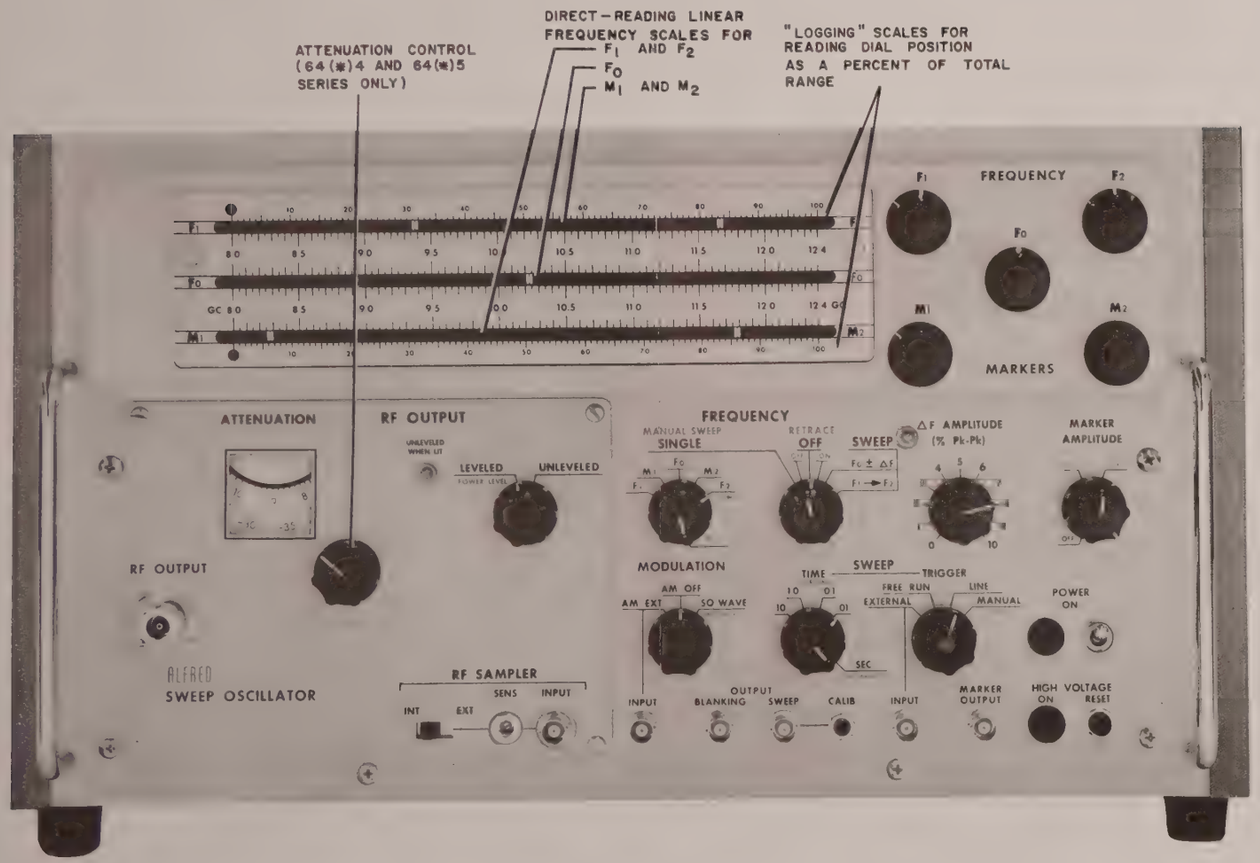


Figure 3-1. Front Panel

Table 3-1. Description of Front Panel Controls and Indicators

Control or Indicator	Function
FREQUENCY Controls SINGLE-OFF-SWEEP Mode Selector Switch	In $F_1 \rightarrow F_2$ SWEEP position, provides a swept rf output starting at the F_1 frequency indicator setting and sweeping to the F_2 frequency indicator setting. The sweep speed and recurrence are controlled by other panel controls. The sweep frequency range (from F_1 to F_2) can be varied from 100% to 2% of the frequency band of the Sweep Oscillator unit by use of the F_1 and F_2 FREQUENCY controls. When in this mode, marker pips are available at the F_0, M_1 and M_2 frequency settings. A sawtooth sweep voltage of +15 V amplitude is available at the SWEEP OUTPUT jack. In $F_0 \pm \Delta F$ SWEEP position, the rf output is swept symmetrically about any F_0 frequency setting (starting at $F_0 - \Delta F$ and sweeping to $F_0 + \Delta F$). ΔF can be varied from 0 to ± 5% of the full frequency band by using the ΔF AMPLITUDE control. This narrow sweep mode may be used to examine small perturbations seen when using the $F_1 \rightarrow F_2$ mode, by setting F_0 to the perturbation frequency and switching to $F_0 \pm \Delta F$ mode. When in this mode, marker pips are available at the M_1 and M_2 settings, and the +15 V sawtooth is available at the SWEEP OUTPUT jack. In OFF position, applies a modulating signal to the microwave oscillator tube, to turn off the rf output power. In single-frequency operation, the OFF position can be used to zero external meters and establish a zero power reference. In all modes of operation, the OFF position can be used to keep the instrument in a "standby" condition. By maintaining filament and cathode voltages during this "standby" condition, the microwave oscillator tube is continuously being outgassed. This tends to extend tube operating life by more than 10%. In SINGLE position, the oscillator output can be any one of five single frequencies determined by the F_0, F_1, F_2, M_1 or M_2 FREQUENCY and MARKER controls. The SINGLE Frequency Selector switch selects any one of the above frequencies for rf output.
SWEEP Light	Glows during rf output sweep in swept-frequency modes.
RETRACE Selector Switch (Red)	Concentric with the Mode Selector switch, this switch is operative only in the swept-frequency modes of operation. In the OFF position, rf power output is removed during retrace; in the ON position, rf power is supplied during retrace.
SINGLE Sweep Frequency Selector Switch	This switch is operative only in the single-frequency mode of operation. It selects one of the FREQUENCY or MARKER controls to set the output frequency (F_0, F_1, F_2, M_1, or M_2).
MANUAL SWEEP Control (Red)	This control functions only when the SINGLE Sweep Frequency Selector switch is in the F_2 position. Concentric with that switch, this control can be turned clockwise to manually sweep the rf output from F_1 to F_2. At the extreme counterclockwise position, the output frequency is F_1. At the extreme clockwise position, the control actuates a switch which locks the output frequency at F_2.
FREQUENCY Dial Control Knobs F_1 and F_2	In the $F_1 \rightarrow F_2$ sweep mode, these controls select the lower and upper limits respectively, of the sweep. In single-frequency mode, they can be used to select output frequencies for final selection by the SINGLE Sweep Frequency Selector switch. The frequency setting of each control is shown by the corresponding indicator bar in the frequency dial (F_1 to the left of F_2 in the $F_1 - F_2$ dial slot). Not operative in $F_0 \pm \Delta F$ sweep mode.
F_0	In $F_0 = \Delta F$ sweep mode, selects the center frequency about which the narrow symmetrical sweep is made. In $F_1 \rightarrow F_2$ sweep mode, and during manual sweep in the F_2 single-frequency mode, provides an absorptive marker pip (if adjusted to a frequency within the swept range). In single-frequency mode, can be used to select an output frequency for final selection by the SINGLE Sweep Frequency Selector switch. The frequency setting is shown by the F_0 dial indicator bar.
MARKERS Control Knobs M_1 and M_2	In $F_1 \rightarrow F_2$ and $F_0 \pm \Delta F$ sweep modes, and during manual sweep in the F_2 single-frequency mode, these controls provide adjustable absorptive marker pips (if adjusted to a frequency within the swept range). In single-frequency mode, can be used to select two output frequencies for final selection by the SINGLE Sweep Frequency Selector switch. The frequency setting of each control is shown by the corresponding indicator bar in the frequency dial (M_1 to the left of M_2 in the $M_1 - M_2$ dial slot). NOTE: In single-frequency mode, the rf output may be swept manually by turning the FREQUENCY or MARKERS control selected by the SINGLE Sweep Frequency Selector switch.
ΔF AMPLITUDE Control	In the $F_0 \pm \Delta F$ sweep mode, adjusts the width of the symmetrical sweep about F_0. The control is calibrated to read sweep width as a % of the full frequency band. Provides maximum 10% sweep width (± 5% of the full frequency band) in the fully clockwise position. Sweep width decreases to zero as the control is turned CCW to 0, where it provides fixed-frequency output at F_0. NOTE: The 0 position is at the CCW rotation limit; it is not a switched position.
MARKER AMPLITUDE Control	In the $F_1 \rightarrow F_2$ and $F_0 \pm \Delta F$ sweep modes, and during manual sweep in the F_2 single-frequency mode, sets the marker amplitude. When INTernal markers are used, controls the absorptive peak height of the rf markers that are visible in the swept rf output. When EXTernal video markers are used, controls the amplitude of these marker pips. The adjustment range provides maximum amplitude at the clockwise limit. The OFF position at the CCW limit of travel turns off all marker signals. NOTE: The OFF position is at the CCW rotation limit; it is not a switched position.
INT-EXT Selector Switch (Red)	Concentric with the MARKER AMPLITUDE control, this switch provides marker pips in the leveled rf output signal when in the INT position. When in the EXT position, it removes the marker pips from the rf output signal and makes available video marker pulses at the MARKER OUTPUT connector. These video marker pulses are negative-going pulses with a width of 5 µs and amplitude of up to ≈ 1 V, adjustable by the MARKER AMPLITUDE control. One pulse is supplied when the sweep crosses M_1, M_2, and F_0. (Marker pulses are not supplied during retrace.)
MODULATION Controls MODULATION Mode Selector Switch	In SQ WAVE position, modulates the rf output with an internally-generated square wave which is adjustable in frequency between 800 and 1200 Hz by means of the concentric red Frequency Vernier Control. Square-wave modulation amplitude is 0 to power level set for all leveled units and all units containing a PIN diode attenuator or output attenuator; and 0 to full-on for all unleveled units not having an attenuator. In AM EXT position, the rf output will be turned off until an external signal is applied. A +10 V signal applied to the AM EXT INPUT connector will turn on the rf signal output to the level set when operation is in leveled mode, and to the maximum output level during unleveled operation. (Higher levels are required for pulsed on-off control; see Paragraph 3.10.2.) In AM OFF position, eliminates all amplitude modulation. Frequency modulation can be used with this or any other position of the switch.

Table 3-1. (Continued)

Control or Indicator	Function
Frequency Vernier Control (Red)	Concentric with the MODULATION Mode Selector switch, this control adjusts the frequency of the internal square-wave modulation in the SQ WAVE modulation mode. Modulation frequency varies between about 800 Hzps in the full counterclockwise position to about 1200 Hzps in the full clockwise position.
SWEEP Controls SWEEP TIME Selector Switch	Selects the time required to sweep from the start frequency to the stop frequency in either automatic sweep mode ($F_1 \rightarrow F_2$ or $F_0 \pm \Delta F$). With the red vernier control fully clockwise in the CALIBRATED position, the SWEEP TIME positions read directly in seconds (0.01, 0.1, 1.0 and 10 seconds).
Sweep Time Vernier Control (Red)	Concentric with the SWEEP TIME Selector switch. When fully clockwise, calibrates that switch to read in seconds. When rotated counterclockwise out of the CALIBRATED position, slows the sweep to increase the sweep time by a factor up to about 10:1 at the fully CCW position. Allows a maximum sweep time of 100 seconds and continuous adjustment between all fixed sweep time settings. NOTE: The CALIBRATED position is at the CW limit of rotation; it is not a switched position.
SWEEP TRIGGER Selector Switch	In EXTERNAL position, a positive pulse signal applied to the EXTERNAL INPUT jack is required to trigger each sweep. Pulse amplitude must be at least +5 V, and pulse width must be at least 10 microseconds. In FREE RUN position, a new sweep is triggered immediately upon the completion of each sweep. Thus, the sweep is recurrent with a period equal to the SWEEP TIME setting. In LINE position, the sweep trigger is synchronized to the power line frequency. In MANUAL position, each sweep must be triggered by pressing the concentric button.
Manual Trigger Pushbutton (Red)	Concentric with the SWEEP Trigger Selector switch. Press to trigger a sweep in the MANUAL sweep mode. Not operative in other sweep modes.
POWER ON Toggle Switch	Turns power on when switched up; removes all power from the instrument when switched down. Adjacent POWER ON indicator glows when the instrument is energized.
HIGH VOLTAGE RESET Pushbutton	Press to reset high voltage after correcting overload condition.
HIGH VOLTAGE ON Light	Glows when high voltage is applied to microwave oscillator tube. When instrument is first turned on, there is a time delay of about 60 seconds before high voltage is applied.
RF OUTPUT Selector Switch	Selects LEVELED or UNLEVELED operation. For leveled operation, external sampling inputs must be applied in the 64(*)0 and 64(*)2 Series units.
POWER LEVEL Control (Red)	Concentric with RF OUTPUT Selector switch. Sets output power level during leveled operation in all units, and during unleveled operation in the 64(*)2, 64(*)3, and 64(*)5 Series. Provides maximum power when fully clockwise; reduces output to the level that permits full-band leveling when turned to a mid-position, and then an additional 5 db (most units) when turned fully counterclockwise.
UNLEVELED WHEN LIT Light	Glows when rf output is unleveled. In leveled operation, glows when power is unleveled over any portion of the band being swept, indicating that the POWER LEVEL setting is too high, or the (external) sampler output is too low.
RF SAMPLER SENS Screwdriver Control	When using an external rf leveling sampler, this control permits adjustment of the internal leveling amplifier sensitivity to match the external sampler output for optimum broadband leveling; see Paragraph 3.12.3. CAUTION USE ONLY NON-METALLIC SCREWDRIVER TO MAKE THIS ADJUSTMENT. FERROUS MATERIALS CAN DAMAGE THE MICROWAVE TUBE.
POWER LEVEL Control (Black) (only on units with output frequency above 12.4 GHz and which do not have internal sampling)	Adjacent to waveguide output flange on these units. Operates waveguide flap attenuator to adjust output power level over a range of about 10 db in all modes of operation.
RF SAMPLER Snap Switch (only on units with internal sampling)	Selects INTernal or EXTernal sampling for leveled operation. For EXTernal sampling, the input from the external detector must be applied to the RF SAMPLER INPUT connector.
ATTENUATION Control & Indicator (only on 64(*)4 and 64(*)5 Series)	Adjacent to ATTENUATION Scale on the 64(*)4 and 64(*)5 Series. Provides a 50-db power control range by adding a known amount of attenuation in the signal output circuit. Readout is in db below the level set with the independent red POWER LEVEL control.

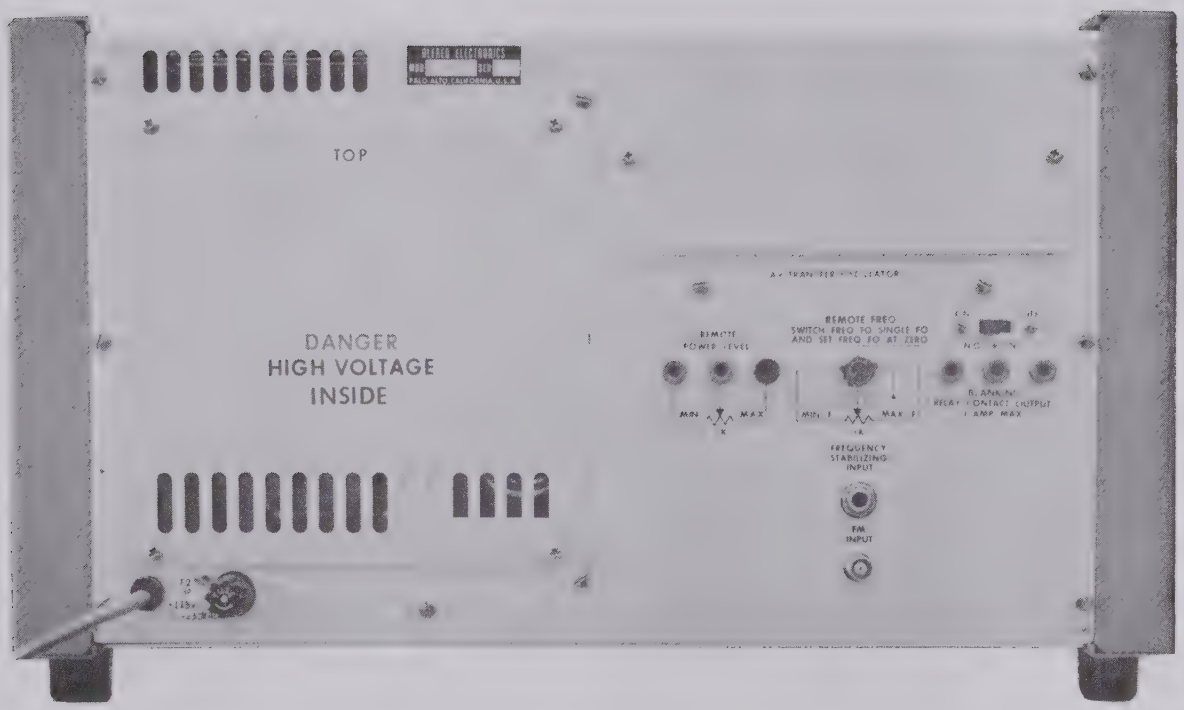


Figure 3-2. Rear Panel

3.2 FRONT PANEL CONNECTORS (See Figure 3-1).

A functional description of all front panel connectors is given in Table 3-2.

Table 3-2. Description of Front Panel Connectors

Connector	Function
BLANKING OUTPUT	Provides a +50 V signal during sweep retrace. Output impedance is 10 K ohms.
SWEEP OUTPUT	Provides a 0 to +15 V sawtooth synchronized with the rf output frequency in either swept or fixed-frequency modes. Output impedance is 10 K ohms. In the $F_1 \rightarrow F_2$ swept output mode, the sawtooth wave tracks the rf output, and is 0 volts at F_1, increasing to +15 V at F_2. In the $F_0 \pm \Delta F$ swept mode, the sawtooth runs the full 0 to +15 V range linearly as the rf output sweeps from $-\Delta F$ to $+\Delta F$. In the single-frequency modes, the output is a dc level linearly proportional to the dial frequency (0 V at low end; +15 V at high end) when M_1, F_0, or M_2 control the frequency output. In the F_2 single-frequency mode (during manual sweep), the output level varies linearly from 0 at a frequency corresponding to F_1 to +15 V at a frequency corresponding to F_2. In the F_1 single-frequency mode, no output is provided. NOTE: The sweep output level is switched to +15 V to permit calibration of the using device when the adjacent CALIB pushbutton is pressed.
EXTERNAL (TRIGGER) INPUT	Permits use of an external trigger signal to trigger each rf output sweep. A signal of +2 V minimum, with a duration of at least 10 µs, actuates the sweep. Input impedance is greater than 10 K.
MARKER OUTPUT	Supplies marker output pulses when the rf output frequency crosses the value set by each FREQUENCY MARKER control (M_1, M_2, and F_0) in any swept mode of operation. The pulses have $\approx$ -1 V amplitude and a width of 5 µs. Output impedance is 1 K ohm. They are supplied only when the MARKER INT-EXT Selector Switch is in the EXT switched position.
AM EXT	Permits input of an external signal to amplitude-modulate the rf output, when the MODULATION Selector switch is in the AM EXT position. In that mode, the rf output will be turned off until an external modulation signal is applied. A +10 V signal will turn on the rf output to the set level in leveled operation or to the maximum level in unleveled operation. For high speed pulse modulation control, a signal of about +100 V peak is required to drive the ac coupling circuit which applies the input directly to the microwave tube. Input impedance is about 2 K ohms shunted by 100 pf. Pulse modulation response is 0.1 µs for full-range on-off in unleveled operation; 10 µs with solid-state leveling and 20 µs with grid-leveling.
RF SAMPLER INPUT	Permits connection of a signal from an external sensing coupler and detector to drive the leveling circuits. A detector input of approximately -100 mv, corresponding to rated rf power output, is required for optimum performance. Input impedance is 2800 ohms.
RF OUTPUT Coax or Waveguide Connector	Supplies the Sweep Oscillator output signal.

3.3 REAR PANEL CONTROLS AND CONNECTORS (See Figure 3-2).

A functional description of all rear panel controls and connectors is given in Table 3-3.

Table 3-3. Description of Rear Panel Controls and Connectors

Control or Indicator	Function
REMOTE POWER LEVEL Banana Jacks	Permits connection of an external 1 K potentiometer to provide remote power level control during leveled operation. (See Paragraphs 3.10.3 and 3.12.4 for details.)
REMOTE FREQ 4-Terminal Connector	Permits connection of an external 1 K potentiometer in a shielded circuit to provide remote frequency control. (See Paragraph 3.11.2 for details.)
BLANKING RELAY CONTACT OUTPUT Banana Jacks	Provides S.P.D.T. relay contact operation during sweep retrace on the two slowest sweep ranges. Both normally-open (N.O.) and normally-closed (N.C.) contacts are available to permit use for recorder pen lift control, etc. The contacts have a maximum capacity of 1 amp.
ON OFF BLANKING Snap Switch	When in OFF position, keeps the blanking relay (described above) de-energized. When in ON position, allows the blanking relay to be energized during sweep retrace.
FREQUENCY STABILIZING INPUT	Permits connection of a signal from an external synchronizer for frequency- or phase-locking the oscillator output at any desired single frequency. The input should not exceed $\pm$ 50 V (+ increases frequency). Input impedance is 10 K ohms. (See Paragraph 3.11.3 for details).
FM INPUT	Permits deviation of the rf output signal from the frequency set by the panel controls by using an externally-applied signal. A signal of 15 V peak-to-peak is sufficient to deviate the output over the full frequency range. Response is dc to 10 KHz. Input impedance is 15 K ohms.

3.4 INSTRUMENT TURN-ON PROCEDURE.

a. Check that the line cord is plugged in and properly grounded.

b. Turn the FREQUENCY Mode Selector switch to OFF.

c. Turn the POWER toggle switch ON.

d. The POWER ON indicator light should glow immediately.

e. After about 60 seconds, the HIGH VOLTAGE ON light should glow. The instrument is now ready to provide rf output.

f. Turn to the appropriate paragraph(s) below for the control settings and operating procedures for the desired mode of operation.

NOTE: The FREQUENCY Mode Selector switch removes the rf output when placed in the OFF position, and keeps the instrument in "standby" condition ready for instant use. Thus, the FREQUENCY Mode Selector switch may be placed in the OFF position until output connections are completed, and during "warmup" periods and other downtime. RF output is instantly restored when the FREQUENCY Mode Selector switch is set to any other position.

3.5 OPERATING PROCEDURES FOR SWEPT-FREQUENCY OUTPUT MODES.

3.5.1 GENERAL. The Model 6400 can be operated in either swept-frequency or fixed frequency modes of operation. In swept-frequency operation, the sweep can be either automatically or manually controlled, using panel controls or remote control signals. There are two automatic sweep modes: the broadband ($F_1 \rightarrow F_2$) sweep and the narrow-band ($F_0 \pm \Delta F$) symmetrical sweep. In many situations the broadband sweep will be used for quick-look testing over a large portion of the band, and the narrow-band sweep can be used to examine areas of interest discovered in the broadband sweep. The ALFRED 6400 Series is unique in that the two sweep modes are set with independent controls, so that operation can be switched quickly from one to the other by simply switching the FREQUENCY Mode Selector switch.

There are two manual sweep modes: one in which the selected "single" frequency is swept by manually turning its frequency control knob, and another in which the MANUAL SWEEP control drives the sweep between preset limits.

3.5.2 BROADBAND ($F_1 \rightarrow F_2$) SWEEP OPERATION

3.5.2.1 BASIC DATA. In the broadband sweep mode of operation, the frequency can be swept over all or any portion of the frequency range of the unit, as determined by the selected start frequency (F_1) and stop frequency (F_2) points. The sweep is always made in the direction of increasing frequency. The time to sweep from F_1 to F_2 can be varied from 10 milliseconds to 100 seconds. During the forward sweep an auxiliary sweep output voltage varying from 0 to +15 V is available for use in driving the horizontal axis of an oscilloscope or recorder. The sweep can be triggered by several alternate means, and the rf output can be either on or off during the retrace interval (after F_2 is reached and until the next sweep is triggered). Various modulation options and marker pips are available. Auxiliary blanking signals are available during retrace.

NOTE: The sweep progresses in the direction of increasing frequency. If downward sweep is desired, use the RETRACE ON feature and select a SWEEP TIME setting that provides the desired retrace sweep speed as tabulated below:

SWEEP TIME Switch Setting	"RETRACE ON" DOWNWARD Sweep Time
10	800 ms
1	80 ms
0.1	20 ms

3.5.2.2 DETAILED PROCEDURE. For broadband sweep operation, turn the instrument on as described in Paragraph 3.4 and make control settings as follows:

FREQUENCY Mode Selector to SWEEP $F_1 \rightarrow F_2$.
RETRACE (red) switch to ON or OFF depending on whether rf output is wanted on or off during the retrace interval between sweeps.
FREQUENCY F_1 Dial Control to desired sweep start frequency.
FREQUENCY F_2 Dial Control to desired sweep stop frequency.
Set SWEEP TIME and SWEEP TRIGGER controls to obtain desired sweep response (see Paragraphs 3.7 and 3.8).
If markers are desired - see Paragraph 3.13.
If markers are not desired - turn MARKER AMPLITUDE control to OFF limit of rotation.
If modulation is desired - see Paragraph 3.9.
If modulation is not desired - turn MODULATION control to AM OFF.
If output leveling or power level adjustment is desired - see Paragraph 3.12.
If output is to be unleveled - turn RF OUTPUT switch to UNLEVELED.
If it is desired to use optional OUTPUT SWEEP sawtooth and BLANKING signals, see Paragraph 3.15.

NOTE: To examine a point of interest observed during the broadband sweep mode, adjust the F_0 control (which operates a marker during $F_1 \rightarrow F_2$ sweep) until its marker is on the point of interest; then switch the FREQUENCY Mode Selector to $F_0 \pm \Delta F$ and the narrow-band sweep (see Paragraph 3.5.3) will automatically be centered on that point.

3.5.3 NARROW-BAND ($F_0 \pm \Delta F$) SYMMETRICAL SWEEP.

3.5.3.1 BASIC DATA. In this mode, a center frequency (F_0) can be set anywhere in the band and the rf is swept symmetrically about this point with a maximum sweep range of ± 5% of the full frequency range. The center frequency can be moved during operation by turning the F_0 control, to allow quick adjustment of the area being examined to any desired point. Sweep time control settings set the time to sweep from $-\Delta F$ to $+\Delta F$. Other control arrangements and auxiliary output signals are essentially the same as in the broadband sweep, except that only two markers are available because the F_0

control (which positions a marker in $F_1 \rightarrow F_2$ sweep) is used to control the sweep center frequency. The same 0 to +15 V dc sweep output is supplied to drive a recorder or scope horizontal axis during the sweep from $-\Delta F$ to $+\Delta F$. Thus, when the operating mode is switched from broadband to narrow-band sweep, this output permits automatic expansion of the display to fill the same horizontal length.

3.5.3.2 DETAILED PROCEDURE. For narrow-band symmetrical sweep operation, turn the instrument on as described in Paragraph 3.4 and make control settings as follows:

FREQUENCY Mode Selector to SWEEP $F_0 \pm \Delta F$.
RETRACE (red) switch to ON or OFF depending on whether rf output is wanted on or off during the retrace interval between sweeps.
FREQUENCY F_0 Dial Control Knob to desired center frequency of narrow-band sweep.
ΔF AMPLITUDE Control to a position corresponding to the desired sweep frequency range, up to a maximum of ±5% of the full instrument band. (See NOTE below.)
Set SWEEP TIME and SWEEP TRIGGER Controls to obtain desired sweep response (see Paragraph 3.7 and 3.8).
If markers are desired - see Paragraph 3.13.
If markers are not desired - turn MARKER AMPLITUDE control to OFF limit of rotation.
If modulation is desired - see Paragraph 3.9.
If modulation is not desired - turn MODULATION control to AM OFF.
If output leveling or power level adjustment is desired - see Paragraph 3.12.
If output is to be unleveled - turn RF OUTPUT switch to UNLEVELED.
If it is desired to use optional OUTPUT SWEEP sawtooth and BLANKING signals, see Paragraph 3.15.

NOTE: To change the center frequency or sweep width, the F_0 and ΔF controls can be adjusted at any time. ΔF remains constant as F_0 is adjusted, unless the ΔF AMPLITUDE control is also adjusted.

3.5.4 MANUAL SWEEP USING MANUAL SWEEP CONTROL.

3.5.4.1 BASIC DATA. In this mode, the rf output can be swept over all or any portion of the full frequency range of the instrument, as determined by the lower end frequency point (F_1) and the upper end frequency point (F_2). The sweep position between these two points is controlled by the position of the MANUAL SWEEP Control, and the sweep may therefore be made in either direction, (or back-and-forth) and at any desired rate. The dc sweep output provided in this mode has the same frequency dependence as in the $F_1 \rightarrow F_2$ automatic sweep, varying linearly from 0 to +15 V as the sweep is manually driven between F_1 and F_2. This feature makes this mode especially convenient for use with recorder readout, since it permits precise frequency positioning with the same horizontal axis calibration as provided in automatic sweep. While the manual sweep back from F_2 to F_1 can be considered a "retrace," there is no rf blanking available and no auxiliary blanking output during this mode. The sweep time and triggering controls are non-functional in this mode, but markers, modulation, and auxiliary dc sweep output are available.

3.5.4.2 DETAILED PROCEDURE. For manual sweep operation using the MANUAL SWEEP Control, turn the instrument on as described in Paragraph 3.4 and make control settings as follows:

FREQUENCY Mode Selector to SINGLE.
SINGLE Frequency Selector to F_2.
FREQUENCY F_1 Dial Control Knob to desired low-frequency end of sweep.
FREQUENCY F_2 Dial Control Knob to desired high-frequency end of sweep.
MANUAL SWEEP (red) Control: turn as desired to electronically sweep the signal between F_1 (at its counterclockwise limit) and F_2 (at its switched clockwise limit).
If markers are desired - see Paragraph 3.13.
If markers are not desired - turn MARKER AMPLITUDE control to OFF limit of rotation.
If modulation is desired - see Paragraph 3.9.
If modulation is not desired - turn MODULATION control to AM OFF.
If output leveling or power level adjustment is desired - see Paragraph 3.12.
If output is to be unleveled - turn RF OUTPUT switch to UNLEVELED.
If it is desired to use optional OUTPUT SWEEP dc signal, see Paragraph 3.15.

NOTE: If the MANUAL SWEEP Control is turned fully CW to its switched F_2 position, the output frequency can then be swept and monitored on the frequency dial by turning the FREQUENCY F_2 Control Knob. To monitor specific frequency points when the MANUAL SWEEP control is operating the sweep (with no indication on the frequency dial), the markers can be utilized.

3.5.5 MANUAL SWEEP USING FREQUENCY CONTROL KNOBS.

3.5.5.1 BASIC DATA. In this mode, the rf output can be swept over all or any part of the full frequency range without using preset start and stop points, and controlled by any one of the FREQUENCY or MARKERS controls. The instantaneous frequency output can thus be monitored on the frequency dial. The other operating features are the same as in the manual sweep mode using the MANUAL SWEEP control, except that markers are available only when the FREQUENCY F_2 Control is used to control the sweep, and the 0 to +15 V sweep output is available only when the M_1, M_2, or F_0 Control is used to control the sweep.

3.5.5.2 DETAILED PROCEDURE. For manual sweep operation using the FREQUENCY Control Knobs, turn the instrument on as described in Paragraph 3.4 and make control settings as follows:

FREQUENCY Mode Selector to SINGLE.
SINGLE Frequency Selector to any position (corresponding to the Control Knob to be used for sweeping the output signal).
FREQUENCY or MARKERS Control Knob selected by the above setting of the SINGLE Frequency Selector: turn as desired to sweep the rf output signal in any desired manner; output frequency is indicated by the corresponding indicator bar on the frequency dial.
MANUAL SWEEP (red) Control to its switched F_2 position (not required unless F_2 is used).
If modulation is desired - see Paragraph 3.9.
If modulation is not desired - turn MODULATION control to AM OFF.
If output leveling or power level adjustment is desired - see Paragraph 3.12.
If output leveling is not desired - turn RF OUTPUT switch to UNLEVELED.

If markers are desired (F_2 Control Mode only) - see Paragraph 3.13.
If markers are not desired in F_2 Control Mode - turn MARKER AMPLITUDE Control to OFF limit of rotation.
If it is desired to use optional OUTPUT SWEEP signal, see Paragraph 3.15.

NOTE: When F_1, F_2, M_1 or M_2 Control Knobs are selected for sweep control, the unused knob which shares the same dial indicator slot should be turned to the corresponding band edge so as not to interfere with the Control Knob and indicator bar being used.

3.6 OPERATING PROCEDURES FOR SINGLE-FREQUENCY OUTPUT MODE.

3.6.1 GENERAL DATA. The instrument can be used to generate fixed (single) frequency rf output that is either unmodulated (CW) or modulated. The output frequency is determined by any one of the five frequency indicators (F_0, F_1, F_2, M_1, or M_2) as selected by a front panel switch; and the frequency indicators are continuously adjustable to provide any desired frequencies within the instrument range. The frequencies can be changed and adjusted as desired during operation. For fixed-frequency operation where only one single frequency is required, the choice of which Control Knob to select is arbitrary. In many cases, however, it will be convenient to be able to switch quickly between up to five pre-selected frequencies which are related to channel limits or other points of interest. In that case, by setting the five frequency indicators to the different frequencies in the order F_1, - M_1 - F_0 - M_2 - F_2, it will be possible to quickly select them in sequence by turning the SINGLE Frequency Selector switch.

NOTE: If frequency modulation is to be used with single-frequency operation, disregard the following procedure and instead follow the procedure of Paragraph 3.5.3.1 for $F_0 \pm \Delta F$ sweep. Turn the ΔF AMPLITUDE control fully CCW to its OFF limit of rotation, and the F_0 control to the desired single frequency. This procedure must be used because the FREQUENCY Mode Selector switch must be set to a SWEEP position to eliminate internal ac feedback which would interfere with fm modulation. External frequency stabilization can be used with the following single-frequency operating procedure (see Paragraph 3.11.3.1 for details).

3.6.2 DETAILED PROCEDURE. For fixed-frequency operation, turn the instrument on as described in Paragraph 3.4 and make control settings as follows:

FREQUENCY Mode Selector to SINGLE.
FREQUENCY and MARKERS Control Knobs: turn one or more controls as desired to select one or more output frequencies for selection by the SINGLE Frequency Selector switch. If several frequencies are desired, the mechanical limitation of the frequency dial will require F_2 to be above F_1, and M_2 to be above M_1. If it is desired to switch between frequencies in ascending or decending order, the indicators used for the various frequencies should be chosen in the same sequence as the positions of the SINGLE Frequency Selector (F_1 - M_1 - F_0 - M_2 - F_2).
SINGLE Frequency Selector to the position corresponding to the dial indicator set at the desired rf output frequency.
MARKER AMPLITUDE Control to its OFF limit of rotation (not required unless F_2 is used).
MANUAL SWEEP (red) Control to its switched F_2 position (not required unless F_2 is used).
If amplitude modulation is desired - see Paragraph 3.9.
If amplitude modulation is not desired - turn MODULATION control to AM OFF.
If output leveling or power level adjustment is desired - see Paragraph 3.12.
If output leveling is not desired - turn RF OUTPUT switch to UNLEVELED.
If output frequency stabilization using an external frequency or phase-locking device is desired - see Paragraph 3.11.3.1.

NOTE: Any or all of the frequencies can be adjusted at any time during use by turning the Control Knobs. The output frequency can be "swept" by adjusting the Control Knob for the output signal in use.

3.7 SELECTION OF SWEEP TIME.

The SWEEP TIME Selector switch controls the time required for each sweep to progress from the start frequency (F_1 or $F_0 - \Delta F$, depending on mode) to the stop frequency (F_2 or $F_0 + \Delta F$). It provides four calibrated positions when the red VARIABLE control is turned to its clockwise CALIBRATED end position. When the VARIABLE control is turned counterclockwise out of the CALIBRATED position, it slows the sweep by a variable amount which increases to 10:1 at the extreme counterclockwise end. Thus, a continuously adjustable sweep time range from 0.01 sec. to 100 sec. is available by proper adjustment of the SWEEP TIME and VARIABLE controls.

The 0.01 and 0.1 second ranges are most convenient for oscilloscope display; the 1.0 second range for small strip chart recorder readout; and the 10 second range for X-Y recorder readout. The 100 second sweep can be used for special applications such as measurement of output power or modulation characteristics with external meters.

3.8 SELECTION OF SWEEP TRIGGER MODE.

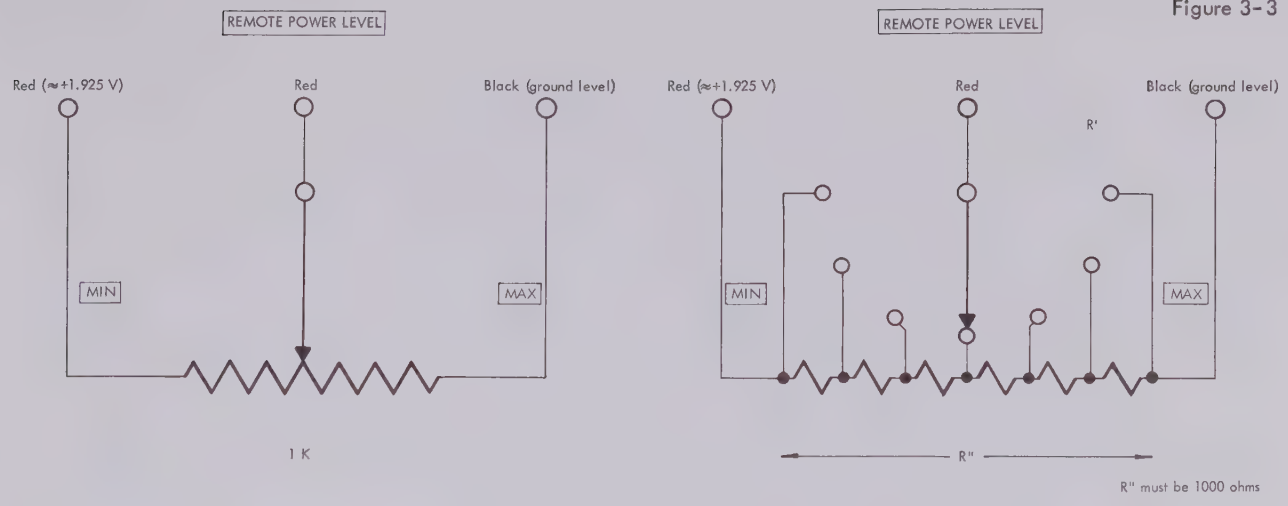
The SWEEP TRIGGER Selector switch positions provide four types of sweep triggering: automatically recurring sweeps triggered either from the LINE or in a FREE RUN mode; MANUAL triggering; or EXTERNAL control of triggering.

Automatically recurring sweeps are most convenient for oscilloscope display. The LINE triggering mode is useful in systems where display or other equipment is line-synchronized; otherwise the FREE RUN mode can be used.

Non-recurring sweep is most convenient for recorder readout, so that just one trace can be triggered after the readout equipment is set-up and calibrated. In the MANUAL switch position, one sweep is triggered each time the red PUSH button is pressed.

The EXTERNAL triggering mode can be used for either automatically recurring or one-shot non-recurring sweeps synchronized with external equipment. In this mode, a signal of at least +5 V with a duration of at least 10 microseconds applied to the EXTERNAL INPUT connector will trigger a sweep (provided that the previous sweep has been completed). Trigger signals received prior to completion of the previous sweep will be disregarded. Thus a pulse train with any convenient PRF* can be used for triggering and synchronizing recurrent sweeps with external equipment if each individual pulse meets the above specifications. For triggering individual sweeps, a single pulse or a positive step-voltage of at least +5 V can be used. Input impedance is greater than 10 K ohms.

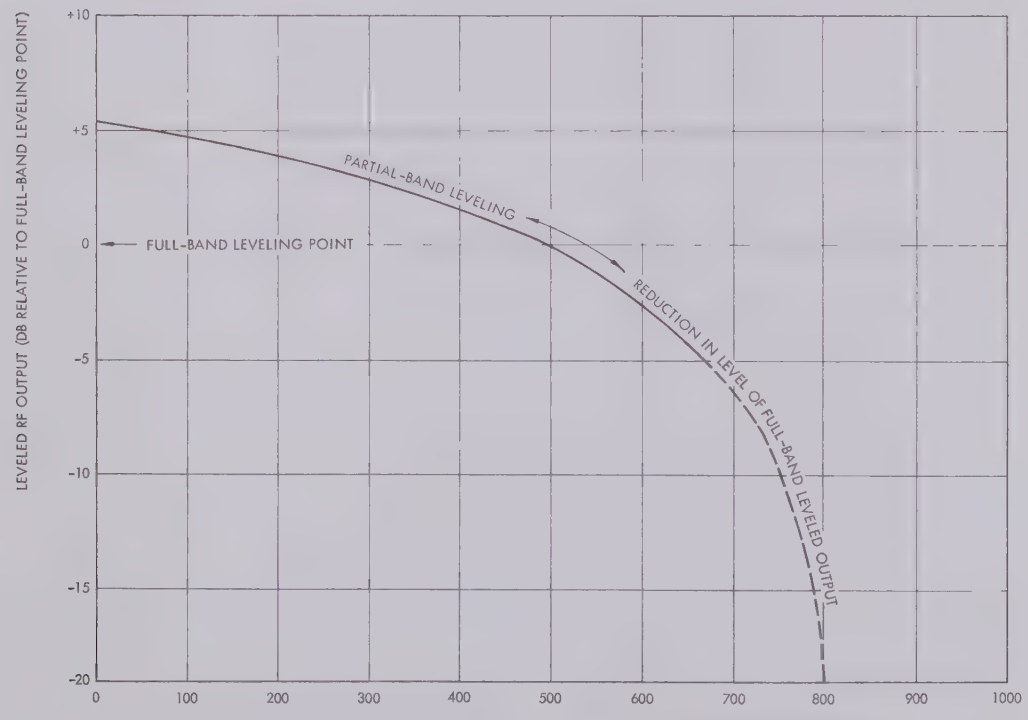
* pulse repetition frequency



A. Circuit Using External Potentiometer

B. Circuit Using Switched Resistive Network

NOTE: THE OUTPUT LEVEL DECREASES TO THE FULL-BAND LEVELING POINT AND THEN AT LEAST AN ADDITIONAL 5 DB AS THE WIPER OF THE 1 K POTENTIOMETER IS MOVED FROM THE "MAX" TO "MIN" LIMIT. A SWITCHED RESISTOR NETWORK PROVIDES SIMILAR RESPONSE. ON PIN DIODE LEVELED UNITS, THE CONROL RANGE IS 10 DB. THE RED POWER LEVEL CONTROL ON THE FRONT PANEL MUST BE TURNED FULLY CLOCKWISE TO ENABLE THE MAXIMUM CONTROL RANGE WITH THE REMOTE POWER LEVEL JACKS. THE FRONT PANEL CONTROL CAN BE USED TO REDUCE THE OUTPUT TO THE LEVELING POINT FOR THE SWEEP RANGE USED. THEN THE REDUCED-RANGE REMOTE ADJUSTMENT WILL BE UNIFORMLY BELOW THE LEVELED VALUE.



NOTE: FOR ACCURATE CONTROL OF A PARTICULAR INSTRUMENT, A SIMILAR INDIVIDUAL CURVE SHOULD BE PLOTTED FOR THAT UNIT.

C. Graph Of Typical Response To Resistance Connected To REMOTE POWER LEVEL Jacks

Figure 3-3. Rear Panel Connections for External Power Level Programming or Amplitude Modulation with Leveled Output

3.9 MODULATING THE RF OUTPUT.

The rf output can be either amplitude modulated (using an external signal or the internal square wave) or frequency modulated (using external signals). Modulation of either type can be used in single-frequency and swept modes of operation, and can be obtained with low-level signal voltages which need not exceed 15 V. The front panel MODULATION switch allows selection of either external (AM EXT) or internal (SQ WAVE) amplitude modulation (ON-OFF type only), or no amplitude modulation (AM OFF). In the AM OFF position, (or either of the other positions if combined modulation is desired), frequency modulation can be obtained by applying a suitable signal to the rear panel FM INPUT connector or by connecting a variable resistance to the rear panel REMOTE FREQ connector. Variable-level amplitude modulation can be obtained by connecting a variable resistance to the rear panel REMOTE POWER LEVEL jacks.

Each of these modulation modes is discussed separately below. The amplitude modulation modes are discussed under Paragraph 3.10, and frequency modulation under Paragraph 3.11.

3.10 AMPLITUDE MODULATION.

3.10.1 INTERNAL (SQUARE WAVE) AMPLITUDE MODULATION. This type of modulation is convenient for use in measurement systems which have an audio-frequency measurement circuit, such as most reflectometer and ratio meter set-ups. For such applications, turn the MODULATION Selector to SQ WAVE and adjust the red Frequency Vernier Control to its midrange position to obtain an output modulation frequency of about 1000 Hz (the standard for most systems). The Frequency Vernier Control permits varying the modulation frequency from about 800 to 1200 Hz when turned clockwise through its range of rotation. This can be used to set the modulating frequency for optimum response with any measurement system. The stability of the square wave frequency is better than 0.2% per hour under a fairly even temperature environment.

With internal square-wave modulation, 100% modulation is obtained, so that the rf output is either full-on (to pre-set level where applicable) or off during each half-cycle of the square wave. During the off portion of the square wave, the tube is biased beyond beam cut-off, so that the ON to OFF ratio is infinite. In the LEVELED condition the rise and fall time is less than 20 µs between the 10% and 90% power points; UNLEVELED response is even faster. The symmetry ratio between the ON and OFF portions of the square wave is between 0.95 and 1.05. The use of square wave modulation does not shift the rf output frequency, nor does it degrade the excellent rf output frequency stability in single-frequency modes.

3.10.2 EXTERNAL "ON-OFF" AMPLITUDE MODULATION. This type of modulation extends the versatility of the instrument to permit many special applications ranging from simple external on-off rf control by an external source to high-speed pulse modulation. When the MODULATION selector is turned to the AM EXT position, the rf output is turned off until a positive signal is applied to the AM EXT INPUT connector. A +10 V signal turns the microwave tube ON, and when the voltage drops below +6 V the tube is turned off. This modulation is of the ON-OFF type and the on to off ratio is infinite. (This EXT AM mode is intended only for ON-OFF type modulation control since it operates digital control circuits. If variable-amplitude control is desired, it should be obtained by means of signals applied to the REMOTE POWER LEVEL jacks, as discussed in Paragraph 3.10.3.)

The rise and fall time, when in the leveled condition, is better than 10 µs with solid-state leveling and 20 µs with grid leveling. When in the unleveled condition, rise and fall time is $\approx$ 1 µs. For high-speed pulsed rf operation, with the output in the unleveled condition, it is possible to obtain rise and fall times of less than 0.1 µs if a pulse generator is used to drive the AM EXT connector. The pulse generator should have a 50-ohm output impedance and should be capable of supplying at least +100 V (to drive the ac coupling circuit connecting directly to the microwave tube) with a rise and fall time better than 0.02 µs. Units operating below 4 GHz may require only +50 V for high-speed pulse modulation. The input impedance of the EXT AM input is approximately 2 K Ω shunted by 100 pf.

3.10.3 EXTERNAL VARIABLE-LEVEL AMPLITUDE MODULATION. (See Figure 3-3.) This mode can be used to obtain amplitude modulation with any desired modulation factor up to an on-off ratio of 10 db or greater. Since this mode makes use of the leveling circuits, the best pulse response rise and fall time is about 10 µs. This type of modulation is available while operating with the rf output in the leveled condition, with either internal or external sampling. With leveled rf output, variable-level amplitude modulation (or remote output level programming) is available through resistive network connections to the REMOTE POWER LEVEL banana jacks in the rear. The procedure is given below:

For this mode, the controls must be set for internal or external leveling operation as described in Paragraph 3.12, and the red POWER LEVEL control must be turned fully clockwise. Then modulation of the output level can be obtained by connecting a 1 K potentiometer or an equivalent resistive network between the three REMOTE POWER LEVEL banana jacks on the rear panel, as shown in Figure 3-3. As the center red terminal connection is adjusted across 1 K resistance between the MAX and MIN jacks, the power level will decrease to the full-band leveling point and then at least 5 db below that level. An overall reduction of maximum power level in this mode can be obtained by turning the front panel POWER LEVEL control, CCW; but when this control is turned out of the fully clockwise position, the control range available from the REMOTE POWER LEVEL jacks will be reduced. While the main purpose of these terminals is to permit remote control of the output level, rather than amplitude modulation, a motor-driven potentiometer or switched network can be used to apply modulation through this circuit. Read Paragraph 3.12.4 for additional data.

3.11 FREQUENCY MODULATION.

The Model 6400 Series Sweep Oscillators provide three modes of frequency modulation and/or external frequency control, each of which has its own input jack(s) and a specific application. The separate jacks, all on the rear panel, are labeled FM INPUT, REMOTE FREQ, and FREQUENCY STABILIZING INPUT.

For most fm modulation applications, the FREQUENCY Mode Selector switch must be in a SWEEP position to eliminate internal ac feedback which would tend to oppose frequency variations. Single-frequency operation for application of fm can be obtained by leaving the sweep untriggered and/or setting ΔF to zero in the $F_0 \pm \Delta F$ swept mode.

The FM INPUT jack is used for frequency-modulating or sweeping the rf output signal by means of applied signal voltages. The REMOTE FREQ jack is used to permit remote adjustment or programming of the rf output frequency by means of an adjustable potentiometer or resistive network. The FREQUENCY

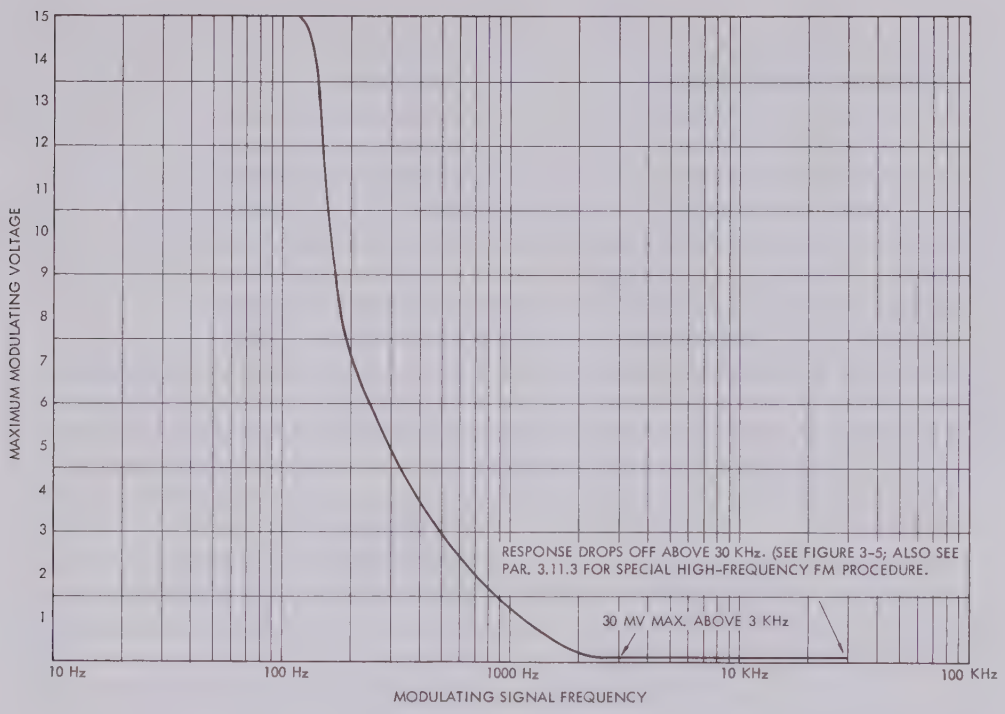


Figure 3-4. Maximum Allowable Modulating Voltage vs. Modulating Signal Frequency for Large-Signal FM Modulation at FM INPUT Jack.

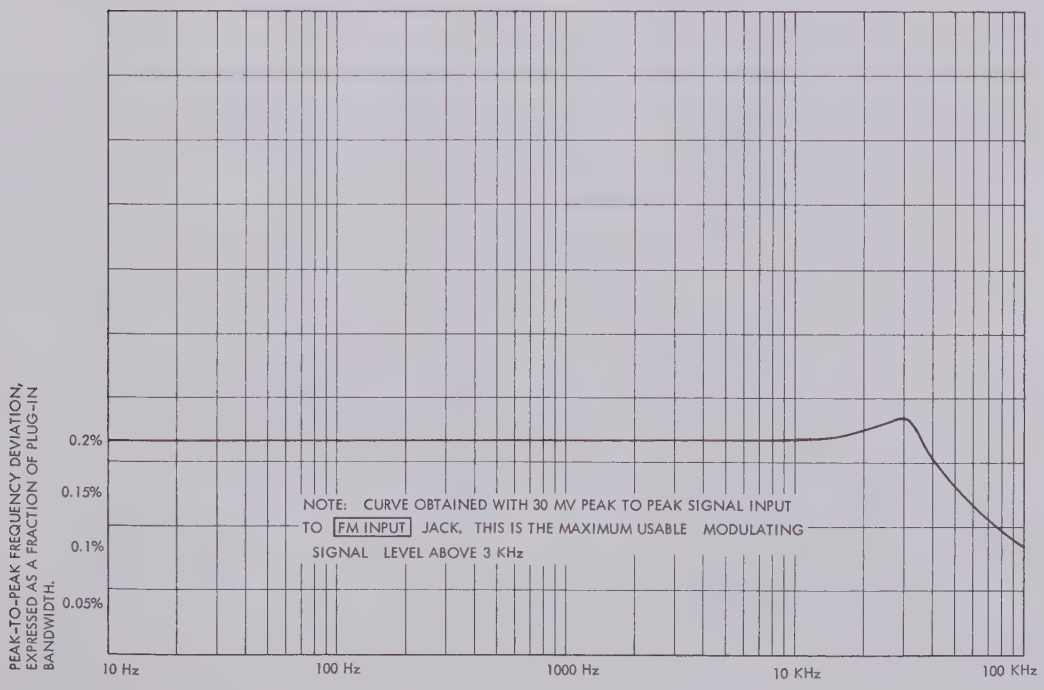

PEAK-TO-PEAK FREQUENCY DEVIATION, EXPRESSED AS A FRACTION OF PLUG-IN BANDWIDTH.
0.2%
0.15%
0.1%
0.05%
NOTE: CURVE OBTAINED WITH 30 MV PEAK TO PEAK SIGNAL INPUT TO FM INPUT JACK. THIS IS THE MAXIMUM USABLE MODULATING SIGNAL LEVEL ABOVE 3 KHz
10 Hz
100 Hz
1000 Hz
10 KHz
100 KHz

Figure 3-5. Modulation Response vs. Modulating Signal Frequency for Small-Signal FM Modulation at FM INPUT Jack.

STABILIZING jack is used to obtain ultra-stable single-frequency output by coupling in feedback error signals from an external synchronizer, such as a frequency discriminator or phase detector. Each of these modes is discussed separately below.

3.11.1 VOLTAGE-CONTROLLED FM USING THE FM INPUT JACK (See Figures 3-4, 3-5, and 3-6).

3.11.1.1 GENERAL DATA. With either swept or single-frequency output, the rf signal can be frequency modulated by applying a signal to the FM INPUT jack. The frequency of the applied modulating signal can be from dc to 10 KHz. With frequency modulation, the instantaneous rf output frequency will be the sum of the frequency called for by the panel controls, and the up-scale or down-scale adjustment called for by the applied modulation. For single-frequency operation, the $F_0 \pm \Delta F$ swept mode is used with ΔF set to zero and F_0 at the desired frequency. With the F_0 control set at the low end of the band in single-frequency operation, a signal of +15 V applied to the FM INPUT jack will drive the output frequency to the high end.

Operation is linear, with an output signal of less than +15 V producing a proportional fraction of a full-range upscale frequency swing. Modulating signals of negative polarity can similarly be used to drive the output frequency below that set by the panel controls. The amount of deviation obtainable by application of a particular modulating voltage is thus proportional to the bandwidth between the frequency limits of the instrument. It is equal to the voltage expressed as a fraction of 15 V times the instrument bandwidth. Maximum deviation obtainable through use of the FM INPUT jack is limited by both the frequency of the modulating signal (which determines how fast the rf must be deviated) and the rf output frequency range of the instrument (which determines how much deviation a given voltage produces). The relationship of permissible modulating voltage to the modulating signal frequency is shown in Figures 3-4, 3-5, and 3-6. Higher-frequency response (which is also non-linear) can be obtained by applying modulation directly to the BWO helix as described in Para. 3.11.3.

> CAUTION: The rf output can never be driven beyond the band-edge frequencies shown on the instrument dial without distortion, and application of excess voltage in an attempt to drive the frequency beyond the high limit of the band may damage the microwave tube.
>
> NOTE: Discussions in this section are in terms of the nominal 0 V to +15 V control range. Due to mechanical limitations in the dial mechanism, the instrument is factory-calibrated to produce the full frequency output range in response to a slightly reduced voltage range, typically +0.15 V to +14.75 V corresponding to the range between 0 and 100 on the dial logging scale. Where absolute accuracy is required in remote control applications, the exact FM INPUT voltage values corresponding to the full-range swing should be determined by actual measurement and substituted in the equations. In most cases, the use of 0 and +15 V will produce an error of less than 1%.

3.11.1.2 FREQUENCY-MODULATING A SINGLE-FREQUENCY OUTPUT. To frequency-modulate a single-frequency rf output or to externally drive a swept-frequency output from any preset starting frequency, proceed as follows:

a. Make the following switch settings:

FREQUENCY Mode Selector to SWEEP $F_0 \pm \Delta F$.
RETRACE switch to ON.
ΔF AMPLITUDE Control to OFF limit of rotation.
SWEEP TRIGGER Selector to MANUAL (so that no internal sweep is triggered; do not push the PUSH button).
FREQUENCY F_0 Control Knob to set the desired starting frequency for fm or externally driven sweep.
Unless simultaneous amplitude modulation is desired - turn MODULATION control to AM OFF.
If simultaneous amplitude modulation is desired - see Paragraph 3.10.
If markers are not desired - turn MARKER AMPLITUDE control to OFF limit of rotation.
If markers are desired - see Paragraph 3.13.
If output leveling or power level adjustment is desired - see Paragraph 3.12.

b. Calculate the signal amplitude to be applied to the FM INPUT jack to achieve the desired frequency modulation, using the following equations:

1) Instantaneous rf output frequency increment, Δf, due to applied modulating voltage:

$$\Delta f = \frac{\text{instantaneous modulating voltage}}{+15} \times \begin{cases}\text{instrument} \\ \text{frequency} \\ \text{range in GHz.}\end{cases}$$

where the instrument frequency range in GHz = (highest dial frequency) - (lowest dial frequency). Note that Δf can be positive or negative, depending on the polarity of the modulating signal.

2) Instantaneous output frequency, F_{output}, due to the combination of internal and external signals:

$F_{output} = \Delta f$ + (indicated single-frequency dial setting)
or
$\Delta f = F_{output}$ - (indicated single-frequency dial setting)

NOTE: To sweep the entire band, set the F_0 frequency indicator to the low end of the band and apply a 0 to +15 V sweep at the FM INPUT jack. If the dial-set output frequency is above the low end of the band, Δf must be reduced accordingly by reducing the modulation voltage, to keep F_{output} within the usable band.

Example A

Conditions:
- Instrument range = 4 to 8 GHz; therefore frequency range = (8 - 4) GHz = 4 GHz
- Indicated frequency = 4.7 GHz (F_0 set to 4.7 GHz)
- Instantaneous modulating voltage = +5 volts

Calculations:
1) Instantaneous frequency increment, Δf: $\Delta f = 5/15 \times 4$ GHz = $1/3 \times 4$ GHz = 1.33 GHz
2) Instantaneous output frequency = 1.33 GHz + 4.7 GHz = 6.03 GHz

Example B

Conditions:
- Instrument range = 4 to 8 GHz; therefore frequency range = (8 - 4) GHz = 4 GHz
- Indicated frequency = 4.7 GHz (F_0 set to 4.7 GHz)
  Instantaneous modulating voltage = -5 V

Calculations:

1) Instantaneous frequency increment, Δf:
   Δf = -5/15 x 4 GHz = -1/3 x 4 GHz = -1.33 GHz
2) Instantaneous output frequency = -1.33 GHz + 4.7 GHz = 3.37 GHz

Thus, it can be seen that a +5 V signal applied to the fm input jack produces an instantaneous frequency of 6.03 GHz, which falls within the frequency limits of the unit (4 to 8 GHz), but the instantaneous frequency produced by the -5 V signal is below the minimum frequency, and will produce distorted output.

Example C

Conditions:

- Instrument range = 8 to 12.4 GHz; therefore frequency range = (12.4 - 8.0) GHz = 4.4 GHz
- Desired starting frequency for externally driven sweep = 9.3 GHz (set F_0 to 9.3 GHz).
- Desired sweep top frequency = 11.7 GHz.

Calculations:

1) Determine the required maximum output frequency increment, Δf, to be produced by the modulating signal to drive from the start frequency to the top frequency, using the F_{output} equation:
   Δf = (11.7 - 9.3) GHz = 2.4 GHz
2) Determine the required maximum modulating signal level to achieve the desired sweep frequency increment, using the Δf equation:

$$2.4\ \text{GHz} = \frac{V_{mod}}{15} \times 4.4\ \text{GHz}$$

(simplify by dividing both sides by 4.4 GHz and multiplying both sides by 15)

$$15 \times \frac{2.4}{4.4} = V_{mod} = +8.2\ \text{volts}$$

Thus, to obtain a linear sweep, a signal varying from 0 to +8.2 volts would be required.

Example D

Conditions:

- Instrument range = 1 to 2 GHz; therefore, frequency range = (2 - 1) GHz = 1 GHz
- Indicated frequency = 1.5 GHz (F_0 set to 1.5 GHz)
- Desired shifted output frequency = 1.05 GHz

Calculations:

1) Determine the output frequency increment, Δf, to obtain the desired frequency-shift performance, using the F_{output} equation:
   Δf = (1.05 - 1.5) GHz = -0.45 GHz.
   Note that the minus sign denotes a frequency decrease.
2) Determine the required modulating signal voltage to achieve the desired frequency shift, using the Δf equation:

$$\Delta f = \frac{V_{mod}}{15} \times 1\ \text{GHz} = -0.45\ \text{GHz}$$

$$V_{mod} = -0.45 \times 15 = -6.75\ \text{volts}$$

Example E

Conditions:

- Instrument range = 7 to 12.4 GHz; therefore frequency range = (12.4 - 7) GHz = 5.4 GHz
- Indicated frequency = 10.5 GHz (F_0 set to 10.5 GHz)
- Desired rf deviation: ± 1.5 GHz

NOTE: A cursory check shows that this is within the frequency range of the instrument, since the maximum and minimum frequencies produced by the deviation are 9 GHz and 12 GHz.

Calculations:

1) Determine the required peak-to-peak frequency deviation, Δf:
   Δf = 2 x 1.5 GHz = 3.0 GHz
2) Determine the required peak-to-peak signal level for an ac signal to produce the desired deviation, using the Δf equation:

$$3.0\ \text{GHz} = \frac{V_{mod}}{15} \times 5.4\ \text{GHz}$$

(Simplify)

$$V_{mod} = 15 \times \frac{3.0}{5.4}$$

V_{mod} = 8.33 volts (peak-to-peak).

Therefore an ac signal of ± 4.16 volts amplitude is required.

c. Apply the proper signal calculated in Step b. to the FM INPUT jack.

NOTE: The frequency of the modulating signal must be within the limits given by Figures 3-4, 3-5, and 3-6. The applied voltage must not be sufficient to drive the output frequency outside the range of the instrument. Violation of either of these rules will produce distorted output.

3.11.1.3 EXTERNALLY DRIVEN FREQUENCY SWEEP. Refer to Paragraph 3.11.1.2 and Figure 3-6.

3.11.1.4 FREQUENCY MODULATION IN SWEPT-FREQUENCY MODES. An externally-driven sweep or single frequency offset can be added to an internal sweep established by the panel controls, using the following procedure:

a. Make the following switch settings:

FREQUENCY Mode Selector to either SWEEP Mode ($F_0 \pm \Delta F$ or $F_1 \rightarrow F_2$).
RETRACE switch to ON.
FREQUENCY F_1, F_2, or F_0 Control Knobs, and ΔF AMPLITUDE Control - set as appropriate for sweep mode selected (see Paragraph 3.5).
If internal sweep is to be synchronized with the modulating signal - set SWEEP TRIGGER Selector to EXTERNAL and apply a suitable external signal in accordance with Paragraph 3.8.
If internal sweep is to be independent of the modulating signal - set SWEEP TRIGGER Selector to FREE RUN, LINE, or MANUAL (see Paragraph 3.8).
SWEEP TIME Control - set for desired sweep response (see Paragraph 3.7).
Unless simultaneous amplitude modulation is desired - turn MODULATION Control to AM OFF.
If simultaneous amplitude modulation is desired - see

Paragraph 3.10.
If markers are not desired - turn MARKER AMPLITUDE control to OFF limit of rotation.
If markers are desired - see Paragraph 3.13.
If output leveling or power level adjustment is desired - see Paragraph 3.12.

b. Calculate the signal amplitude to be applied to the FM INPUT jack to achieve the desired modulation, using the basic equations given above in 3.11.1.2 b. Consider the limiting conditions that will occur at the high-frequency and low-frequency limits of the sweep due to both the internal and external signals. Select modulation voltages that will not drive the rf output outside the frequency range of the instrument.

Example A

Conditions:
. Instrument range = 4 to 8 GHz; therefore frequency range = (8 - 4) GHz = 4 GHz
. Indicated sweep mode and limits: $F_1 \rightarrow F_2$, with F_1 = 4.5 GHz, F_2 = 6.5 GHz
. Desired rf deviation: ± 0.5 GHz

NOTE: This is the greatest available deviation for the above conditions, since the -0.5 GHz swing at the low end of the sweep will drop the output frequency to the 4.0 GHz lower limit of the instrument.

Calculations:
1) Determine the required peak-to-peak frequency deviation, Δf:

$\Delta f = 2 \times 0.5 \text{ GHz} = 1 \text{ GHz}.$

2) Determine the required peak-to-peak signal level for an ac signal to produce the desired deviation, using the Δf equation:

$$1 \text{ GHz} = \frac{V_{mod}}{15} \times 4 \text{ GHz}$$

(simplify by dividing both sides by 4 GHz and multiplying both sides by 15)

$$15 \times \frac{1}{4} = V_{mod}$$

V_{mod} = 3.75 volts (peak-to-peak).

Therefore, an ac signal of ± 1.875 volts amplitude is required.

Example B

Conditions:
. Instrument range = 8 to 12.4 Ghz, therefore frequency range = (12.4 - 8.0) GHz = 4.4 GHz
. Indicated sweep mode and limits: $F_0 \pm \Delta F$, with F_0 set at 10.2 GHz and ΔF set to 10% (± 0.22 GHz)
. Desired external frequency control: Set the narrow-band center frequency F_0 to 9.0 GHz and 11.5 GHz.

NOTE: A cursory check shows that this is within the frequency range of the instrument, since the overall minimum and maximum limit frequencies as the output varies from -ΔF to +ΔF will be 8.78 GHz and 11.72 GHz.

Calculations:
1) Determine the frequency deviation, Δf, required for each of the center-frequency steps, using the F_{output} equation:

$\Delta f_1 = (9.0 - 10.2) \text{ GHz} = -1.2 \text{ GHz}$

Note that the minus sign denotes a frequency decrease

$\Delta f_2 = (11.5 - 10.2) \text{ GHz} = 1.3 \text{ GHz}$

2) Determine the required modulating signal voltage to achieve each desired frequency shift, using the Δf equation:

$$\Delta f_1 = \frac{V_{mod}}{15} \times 4.4 \text{ GHz} = -1.2 \text{ GHz}$$

(Simplify)

$$V_{mod} = \frac{-1.2}{4.4} \times 15 = -4.099 \text{ volts for } \Delta f_1$$

$$\Delta f_2 = \frac{V_{mod}}{15} \times 4.4 \text{ GHz} = 1.3 \text{ GHz}$$

(Simplify)

$$V_{mod} = \frac{1.3}{4.4} \times 15 = 4.432 \text{ volts for } \Delta f_2$$

c. Apply the proper signal calculated in Step b. to the FM INPUT jack.

NOTE: The frequency of the modulating signal must be within the limits given by Figures 3-4, 3-5, and 3-6. The applied voltage must not be sufficient to drive the output frequency outside the range of the instrument. Violation of either of these rules will produce distorted output.

3.11.2 REMOTE FREQUENCY PROGRAMMING USING THE REMOTE FREQ JACK (See Figures 3-6 and 3-7). The REMOTE FREQ connector on the rear of the instrument can be used for frequency programming using external resistors. When remote frequency programming is used, the rf output frequency will be the frequency called for by the panel controls, increased by the programmed frequency increment. The response time is the maximum time it will take for the frequency to be within the specified tolerance of frequency and residual fm. The minimum response time can be determined from Figure 3-6, using the right-hand vertical scale.

NOTE: Because frequency-stabilizing ac feedback is supplied internally in the SINGLE position of the FREQUENCY Mode Selector switch, a single frequency obtained through this mode should be used for remote frequency programming if a response time slower than 100 milliseconds is satisfactory. If response to program changes must be faster than 100 milliseconds, the symmetrical sweep mode ($F_0 \pm \Delta F$) should be used, with ΔF set at 0 and no trigger applied.

For remote frequency programming, the programming potentiometer or resistors must be connected as shown in Figure 3-7. Proceed as follows:

a. Make the following switch settings:

FREQUENCY Mode Selector (see note above) - If response of 100 milliseconds is satisfactory, set to SINGLE and turn SINGLE Frequency Selector switch to F_0. Otherwise, set to SWEEP $F_0 \pm \Delta F$.
RETRACE switch to ON.
ΔF AMPLITUDE Control to OFF limit of rotation.
SWEEP TRIGGER Selector to MANUAL (so that no internal sweep is triggered; do not push the PUSH button).
FREQUENCY F_0 Control Knob to set the desired starting frequency for fm or externally driven sweep.
Unless simultaneous amplitude modulation is desired - turn MODULATION control to AM OFF.

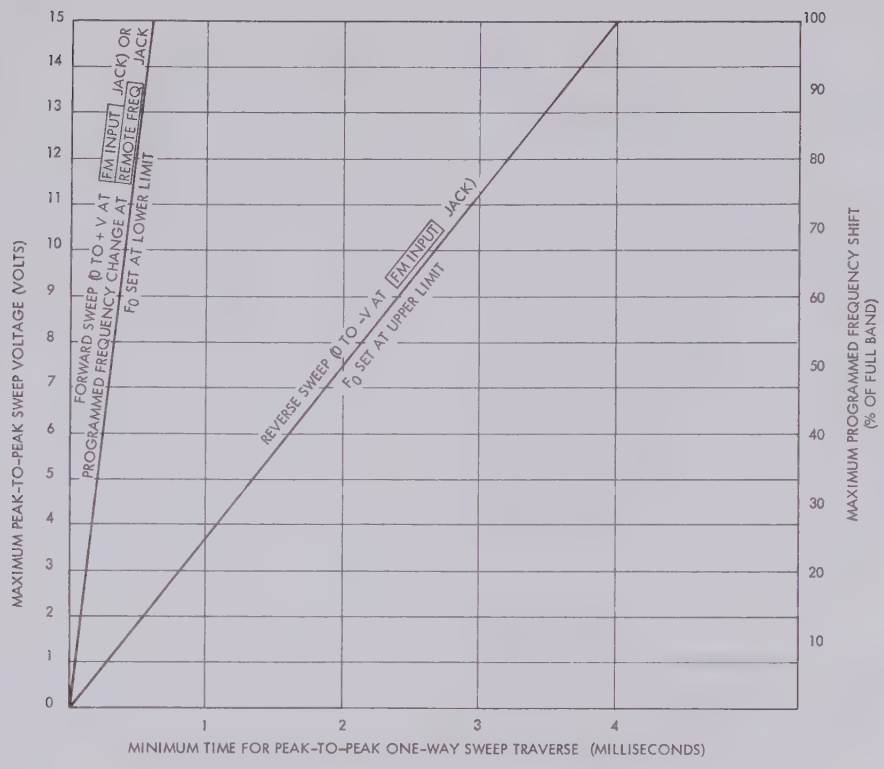
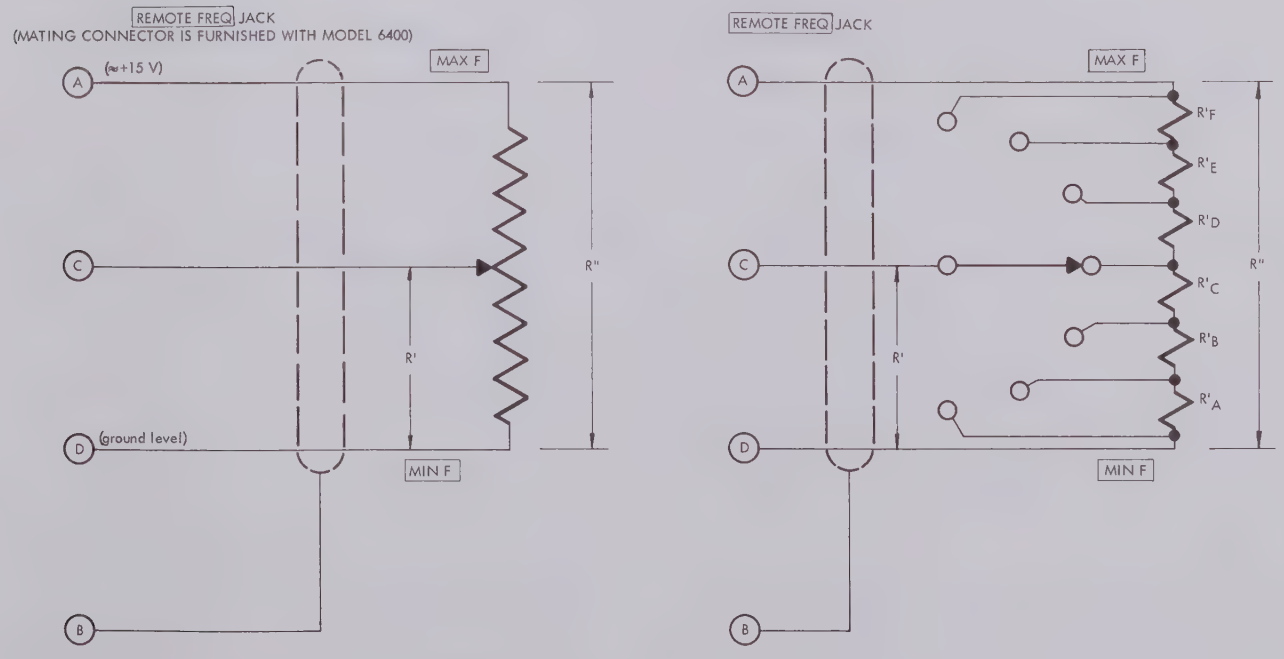

MAXIMUM PEAK-TO-PEAK SWEEP VOLTAGE (VOLTS)
MAXIMUM PROGRAMMED FREQUENCY SHIFT (% OF FULL BAND)
MINIMUM TIME FOR PEAK-TO-PEAK ONE-WAY SWEEP TRAVERSE (MILLISECONDS)
FORWARD SWEEP @ TO + V AT FM INPUT JACK) OR REMOTE FREQ JACK
PROGRAMMED FREQUENCY CHANGE AT F0 SET AT LOWER LIMIT
REVERSE SWEEP @ TO -V AT FM INPUT JACK)
F0 SET AT UPPER LIMIT

Figure 3-6. Maximum Frequency-Shift Rate for Externally Driven Sweep or External Frequency Programming.



NOTES:

1. R" MUST BE 1000 OHMS.
2. OUTPUT FREQUENCY = $\frac{R'}{1000} \times$ FREQUENCY RANGE + FREQUENCY SET WITH PANEL F_0 CONTROL

A. Continuous Range Programming Using External Potentiometer.

B. Stepped Programming Using Switched Resistive Network.

Figure 3-7. Rear Panel Connections for Remote Frequency Programming.

If simultaneous amplitude modulation is desired - see Paragraph 3.10.
If markers are not desired - turn MARKER AMPLITUDE Control to OFF limit of rotation.
If markers are desired - see Paragraph 3.13.
If output leveling or power level adjustment is desired - see Paragraph 3.12.

b. Calculate the potentiometer wiper position or resistor network values required for connection to the REMOTE FREQ jack. Refer to Figure 3-7 and use the following equations:

1) RF output frequency shift, Δf, due to programming resistors:

$$\Delta f = \frac{R'}{R''} \times \text{instrument frequency range in GHz}$$

where the instrument frequency range in GHz = (highest dial frequency) - (lowest dial frequency)

NOTE: R" must be 1000 ohms.

Example A

Conditions:
. Instrument range = 4 to 8 GHz; therefore frequency range = (8 - 4) GHz = 4 GHz.
. Frequency setting = 4.00 GHz (F_0 set to 4.00 GHz)
. R_1 = 427 ohms.

Calculations:
1) RF output frequency shift, Δf:

$$\Delta f = \frac{427}{1000} \times 4 \text{ GHz} = 1.708 \text{ GHz}$$

2) Actual rf output frequency = 1.708 GHz + 4.00 GHz = 5.708 GHz

Example B

Conditions:
. Same as Example A, except frequency setting 7.00 GHz (F_0 set to 7.00 GHz)

Calculations:
1) RF output frequency shift, Δf, = 1.70 GHz (same as Example A).
2) Actual rf output frequency = 1.708 GHz+7.00 GHz = 8.708 GHz

In the first example the output frequency is less than the upper frequency limit of the unit, and the resistor value is acceptable. In the second example the resistor value is not acceptable, because of the frequency setting of the panel controls, since the calculated frequency is greater than the upper frequency limit of the instrument. Connection of such a resistor would produce distortion and possible damage the microwave tube.

Example C

Conditions:
. Instrument range = 8 to 12.4 GHz; therefore frequency range = (12.4 - 8) GHz = 4.4 GHz
. Frequency setting = 8.5 GHz (F_0 set to 8.5 GHz)
. Desired external programming: set the output frequency to 9.6, 10.8, and 12.0 GHz.

Calculations:
1) Determine the output frequency shift, Δf, required for each step:

Δf_1 = (9.6 - 8.5) GHz = 1.1 GHz
Δf_2 = (10.8 - 8.5) GHz = 2.3 GHz
Δf_3 = (12.0 - 8.5) GHz = 3.5 GHz

2) Determine the corresponding value of R' for each step, using the Δf equation:

$$\Delta f_1 = 1.1 \text{ GHz} = \frac{R'_1}{1000} \times 4.4 \text{ GHz}$$

(simplify by multiplying both sides by 1000 and dividing both sides by 4.4 GHz)

$$R'_1 = 1000 \times \frac{1.1}{4.4} = 100 \times 1/4 = 250 \text{ ohms}$$

$$\Delta f_2 = 2.3 \text{ GHz} = \frac{R'_2}{1000} \times 4.4 \text{ GHz}$$

(simplify)

$$R'_2 = 1000 \times \frac{2.3}{4.4} = 523 \text{ ohms}$$

$$\Delta f_3 = 3.5 \text{ GHz} = \frac{R'_3}{1000} \times 4.4 \text{ GHz}$$

(simplify)

$$R'_3 = 1000 \times \frac{3.5}{4.4} \times 795 \text{ ohms}$$

3) Calculate the values of resistors R_A, R_B, R_C and R_{DEF} to use in the program circuit shown in Figure 3-7.

By reference to Figure 3-7, $R_A + R_B + R_C + R_{DEF}$ = 1000 ohms

$R_A + R_B + R_C = R'_3$ calculated above = 795 ohms

Thus, R_{DEF} = 1000 ohms - 795 ohms = 205 ohms
$R_A = R'_1$ calculated above = 250 ohms
$R_B = (R'_2$ above $- R_A)$ = 523 ohms - 250 ohms = 273 ohms
$R_C = R'_3$ above $- (R_A + R_B)$
= 795 ohms - 523 ohms = 272 ohms

NOTE: The input impedance of the remote programming input is 15 K ohms. Because of this it is required that the total resistance of the external resistors (R") be 1 K ohms. This value is equal to that of the panel frequency controls. If some other value is used, the calibration based on the equations above will not be exact because of the different loading effect of the 15 K input impedance.

c. Connect the 1 K potentiometer or resistor circuit, set up according to the above calculations, to the REMOTE FREQ jack as shown in Figure 3-7.

3.11.3 REMOTE FREQUENCY STABILIZING AND HIGH FREQUENCY FM MODULATION (APPLIED TO BWO TUBE HELIX) (See Figure 3-8). The FREQUENCY STABILIZING input jack can be used to apply error signals from a frequency discriminator or phase discriminator for frequency - or phase-locking the Model 6400 Series in any single-frequency output mode when the FREQUENCY Mode Selector switch is in the SINGLE position. It can also be used to apply high frequency fm in either swept mode, including untriggered sweep to allow fm modulation of single-frequency outputs. Modulating signal frequencies can be higher than those acceptable by the FM INPUT jack. The FREQUENCY STABILIZING input jack is a three-terminal closed-circuit phone jack located on the rear

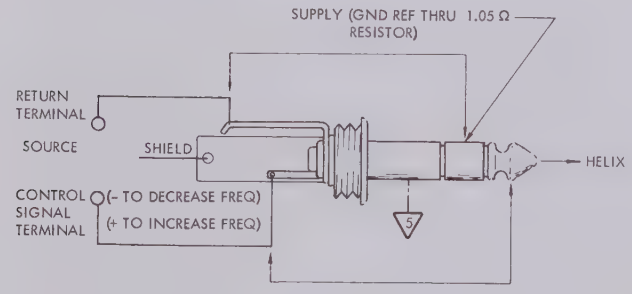
of the instrument. It provides high frequency response because it applies a modulating voltage directly to the helix lead of the BWO tube.

For all tubes, the voltage applied to this input should not exceed the limits of +50 volts and -50 volts. The applied signals will vary the frequency from that established by the panel controls. A positive voltage will increase the frequency, and a negative voltage will decrease the frequency. The response versus voltage is not linear, and the sensitivity and exact response characteristic depend upon the microwave tube used. These characteristics vary somewhat between individual tubes of the same model as well as between frequency bands, so that some experimentation will be required to achieve calibrated results.

The signal source required for this input must be floating and capable of supplying the required helix current to the BWO. This current requirement is given in Addendum A. Since the helix is operated only a few millivolts below ground, no high voltage insulation is required.

The high frequency response of this helix modulation circuit is in the megacycle range, and is normally limited by the ability of the signal source to drive the circuit input capacitance. This capacitance, due to terminal connections and wiring, etc., is about 100 pf. Frequency- and phase-lock response approaches the nanosecond range, and over-all loop stability is again usually limited by the ability of the discriminator or synchronizer used to drive the helix.

Separate procedures are given below for frequency stabilization and for high frequency fm modulation.



NOTES:
1. USE SWITCHCRAFT #297 3-CIRCUIT PHONE JACK.
2. DO NOT EXCEED ± 50 V CONTROL SIGNAL.

Figure 3-8. Rear Panel Connections for Remote Frequency Stabilization or High-Frequency FM Modulation.

3.11.3.1 PROCEDURE FOR REMOTE FREQUENCY STABILIZATION. Proceed as follows:

a. Place the instrument in operation for any single-frequency mode, following the procedure of Paragraph 3-6.

b. Tap off a portion of the rf output signal through a coupler to drive the external discriminator or synchronizing device.

c. Connect the discriminator output through a shielded two-conductor cable to a three-terminal phone jack which mates with the REMOTE FREQUENCY STABILIZING jack, as shown in Figure 3-8. Be sure to observe the proper polarity sense.

d. Adjust the discriminator or synchronizer output as necessary to obtain optimum stabilization.

3.11.3.2 PROCEDURE FOR HIGH-FREQUENCY FM MODULATION. Proceed as follows:

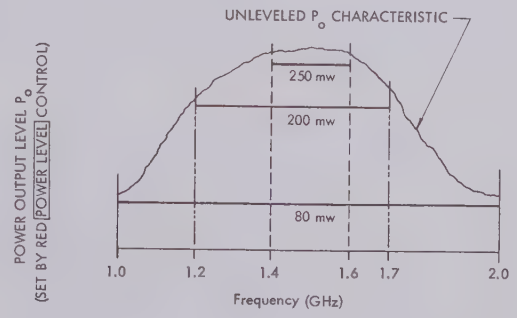
a. For modulation in single-frequency modes, make switch settings as directed in Paragraph 3.11.1.2 a. For modulation in swept-frequency modes, make switch settings as directed in Paragraph 3.11.1.4 a.

b. Connect the modulating signal through a shielded two-conductor cable to a three-terminal phone jack which mates with the REMOTE FREQUENCY STABILIZING jack, as shown in Figure 3-8. Be sure to observe the proper polarity sense.

c. Note that the applied modulation must not be allowed to drive the rf output frequency outside the range of the instrument. The instantaneous frequency output will be the indicated single-frequency dial setting plus the increment due to signal applied to the helix. Separate calculations or empirical checks must be made for each tube if a particular known deviation is required because of sensitivity variations.

3.12 RF OUTPUT LEVELING AND POWER LEVEL ADJUSTMENT.

3.12.1 GENERAL DATA. (See Figures 3-9 and 3-10). All instruments include a leveler-amplifier to permit rf power output leveling and power level adjustment when used with an



NOTE: THE RED POWER LEVEL CONTROL ADJUSTS THE POWER LEVEL TO A POINT WHERE FULL-BAND LEVELING TAKES PLACE WHEN TURNED TO A MID-RANGE POSITION. TURNED CLOCKWISE FROM THAT POSITION, IT RAISES THE OUTPUT POWER LEVEL FOR NARROW-BAND LEVELING AS ILLUSTRATED ABOVE. TURNED COUNTERCLOCKWISE FROM THAT POSITION, IT REDUCES THE FULL-BAND LEVELED OUTPUT OVER A RANGE OF ABOUT 5 DB ON UNITS WITH GRID LEVELING, AND 10 DB ON UNITS WITH PIN DIODE LEVELING.

Figure 3-9. Typical Leveler Performance.

appropriate sampler. The 64(*)1, 64(*)3, 64(*)4, and 64(*)5 Series have an internal rf sampler. These units can be leveled with or without an external rf sampler. The 64(*)0 and 64(*)2 instruments can provide output leveling only if an external sampler is used.

The rf output level can be adjusted in all units when operating in the leveled mode, and in all units except the 64(*)0 and 64(*)1 Series when operating in the unleveled mode. The 64(*) units have 12.4 GHz which contain a flap attenuator provide 10 db power level adjustment range in the unleveled mode.

Leveling of the rf power source is useful for many applications because system output variations can then be directly attributed to the equipment under test. The power output characteristic of microwave oscillator tubes is not constant through the frequency range of each tube. A typical power output characteristic of an unleveled BWO tube is bell-shaped, with 6 to 8 db higher power at band center, and with some lesser narrow-band variations superimposed across the band. When operating with internal leveling, these power variations at the RF OUTPUT connector can be held to within the limits shown in Table 1-2 for each instrument (generally ± 0.3 db) across the full bandwidth of the instrument. By using the external leveling mode (all instruments) with a suitable external sampler located at the load, power variations at a remote load can be kept to within the same limits.

The RF OUTPUT jack of the instruments with internal sampling is physically the primary output terminal of the internal sampling coupler. Therefore, "at-the-load" leveling performance with internal leveling can be obtained by connecting the load directly to the RF OUTPUT jack. The internal low-pass filter (in most units) contained in the instrument provides adequate isolation with most loads. (This element is located between the microwave tube and the internal sampling coupler, and is thus within the leveled loop for either internal or external leveling.) Where the load cannot be connected directly to the RF OUTPUT jack, additional level variations will be produced in the signal supplied to the load by the unavoidable mismatch present in the connecting coaxial or waveguide line(s) and other intermediate components. In this case, improved performance can be obtained with "at-the-load" leveling using an external sampler located at the input terminal to the load.

In all units, whenever external sampling is used, the sampler should be located at the load if possible, and otherwise as close to the load as possible, to minimize VSWR-producing components between the leveled loop and the load.

The leveler-amplifier system used in ALFRED sweepers develops an amplitude-correcting feedback signal by comparing the signal level from the internal or external sampling detector with a reference signal set by the POWER LEVEL control. In leveled operation, when the POWER LEVEL control setting corresponds to a level higher than the unleveled power output over part of the band, the leveler is operative over only that portion of the band that can be leveled to the selected value. On units with internal sampling, the sensitivity of the internal detector circuit is set to provide full-bandwidth leveling at a mid-range position of the red POWER LEVEL control. This allows the power level to be adjusted to a higher value for narrow-band leveling. It also allows at least a 5 db adjustment of output power level with full-band leveling.

Full-band leveling can be provided at a level that is within 1 db of the minimum-power point of the unleveled output characteristic. Similarly, leveling over any portion of the band can be obtained at a level that is within 0.5 db of the minimum-power point of the unleveled output characteristic within that portion of the band. Thus, over narrow mid-band ranges where the available power from the BWO tube is higher than at band edges, higher than rated fullband leveled power may be obtained, as shown in Figure 3-9. The UNLEVELED light goes out only when the output power is leveled over the frequency band being swept.

For external leveling, the detector used must be able to develop about -100 mv (-60 mv minimum output power available under full-band-leveled conditions. Input impedance of this jack is about 3 K. The RF SAMPLER SENS screwdriver control adjusts the sensitivity of the leveler-amplifier to the external sampler, to allow the detector signal to be balanced against the internal reference at the desired setting of the red POWER LEVEL control.

The basic external leveling loop for obtaining optimum power leveling at the load is shown in Figure 3-10A. It consists of a directional coupler to sample a portion of the rf output, and a detector to convert the sampled rf into a dc signal for the leveler-amplifier. An external 3 db pad or low-pass filter to isolate load mismatch from the oscillator tube is not normally required because of the internal isolation provided. The ALFRED Model 1001 Crystal Detector can be used with power levels up to 100 mw. It requires no more than 1 mw input power to develop -60 mv when driving the 3000-ohm input impedance of the RF SAMPLER INPUT jack. The Model 1001 Detectors have exceptionally uniform, matched characteristics. They provide square-law performance within 0.5 db from low level up to 1 mw, and have a sensitivity of greater than 0.5 mv/μw at low levels. These features are advantageous where the leveler sampler circuit is to be matched with the reflected power sampler circuit in reflectometer measurements, as discussed in Paragraph 3.17.3.

An improved external leveling loop using an ALFRED RF Sampler for leveling at the load is shown in Figure 3-10B. These sampler units contain crystal detectors installed directly on the secondary arm of a high-directivity coupler, providing an integrated rf-to-dc transducer with excellent matched wideband response characteristics. A sampler should be chosen which provides at least 1 mw into the detector arm at the output level to be used. Performance details of each unit of the ALFRED RF Sampler Series are available from the factory. Output is at least -60 mv with 1 mw coupled into the detector arm.

An alternate method of external leveling which provides an additional power level adjustment range up to 50 db is shown in Figure 3-10C. This method uses the ALFRED Models 1151-1153 Sampler Attenuators which consist of an ALFRED RF Sampler followed by a precision variable attenuator. The variable attenuator is actually a variable directional coupler and its frequency response is very carefully matched with that of the sampler, so that exceptionally flat output over a wide frequency and attenuation range is obtained. Power variation across the band at any level with a 20-db range can be held to within ± 0.5 db with this arrangement. Models 64(*) and 64(*)5 contain an internal Sampler-attenuator equivalent to the Model 1151-1153.

In units with PIN diode leveling, the output leveling is provided by solid-state attenuation in the output circuit while the oscillator tube continues to operate at full power. Thus, level correction is made independently of the tube and excellent frequency stability is maintained. In other units which have grid-leveled BWOs, some frequency pulling will take place during leveling. This is an inherent characteristic of BWO tubes.

The procedures for each type of leveling and power level adjustment are given separately below.

3.12.2 LEVELING WITH INTERNAL SAMPLING (64(*)1, 64(*)3, 64(*)4, 64(*)5 UNITS ONLY). Proceed as follows:

a. Set all controls as directed in the preceeding paragraphs, to obtain the desired operating conditions.

b. Make the following control settings on the plug-in panel:

RF OUTPUT Selector switch to LEVELED.
RF SAMPLER Snap switch to INT.

c. The red POWER LEVEL Control will reduce the leveled output power to the value required for full-band leveling on all units, and then an additional 5 db or more, when turned from its fully clockwise position to its fully counterclockwise position (see Figure 3-9). Set this control to the desired level. The UNLEVELED light will go off when the output is leveled over the frequency band being swept. On grid-leveled BWO units, do not attempt to reduce leveled power more than 5 db below the minimum unleveled output power. On solid-state leveled units, the full available control range may be safely used.

d. For remote control of output level, turn the red POWER LEVEL control fully clockwise and connect a level-programming network to the REMOTE POWER LEVEL banana jacks on the rear panel as shown in Figure 3-3.

e. On units with an internal sampler-attenuator, up to 50 db power control can be utilized by adjusting the black ATTENUATION knob to its desired level. Leave this control at 0 db if no attenuation is desired.

3.12.3 LEVELING WITH EXTERNAL SAMPLING (ALL UNITS). Proceed as follows (See Figure 3-10):

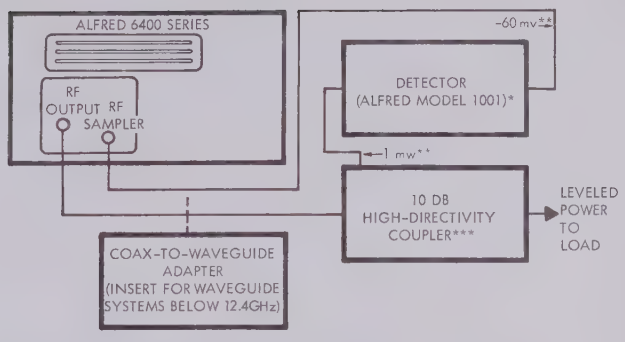
a. Connect to the RF OUTPUT line a suitable sampling coupler and detector to develop an output of -100 mv (-60 mv, minimum) corresponding to the minimum-output point in the spectrum. Connect the output of the sampler detector to the RF SAMPLER INPUT jack, which has an input impedance of approximately 3 K ohms. The ALFRED Models 1151 to 1153 Sampler-Attenuators combine a sampling coupler, detector, and attenuator in one convenient package. The ALFRED Model 1001 Crystal Detector is also available for use with standard couplers. Use high-directivity couplers to minimize leveling error due to reflected power from high-VSWR loads.

b. Set all controls (except leveling controls) as directed in the preceeding paragraphs, to obtain the desired operating conditions.

c. Make the following additional control settings:

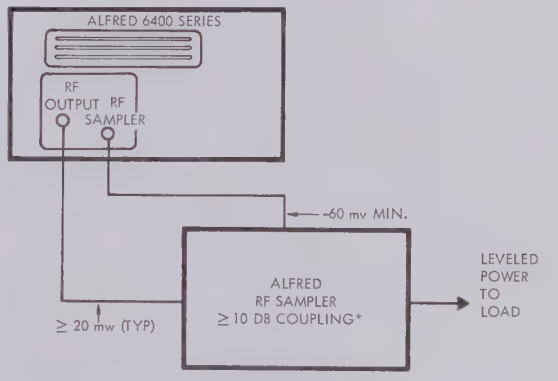
RF OUTPUT Selector switch to LEVELED.
RF SAMPLER Snap switch (if present) to EXT.
ATTENUATION knob (64(*)4 & 64(*)5 only) to 0 db.

d. Observe the output leveling performance across the band, by temporarily connecting the termination (or a second coupler) on the RF OUTPUT line to a power meter or oscilloscope, through a suitable detector such as the ALFRED Model 1001. Sweep across the frequency range of interest and check whether the output is leveled. Full-band leveled performance should be obtained with the red POWER LEVEL control turned to a mid-range position. This will



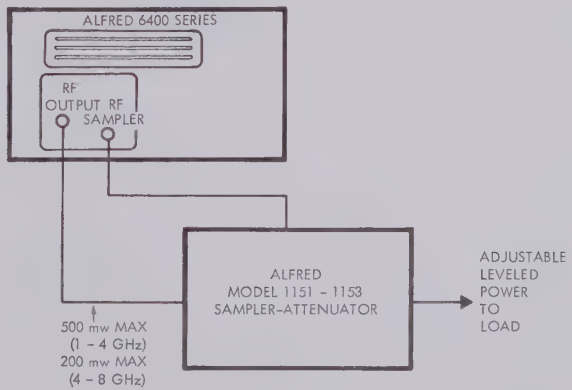
*ABOVE 12.4 GHz, USE A SUITABLE ALTERNATE DETECTOR.
**MINIMUM REQUIRED FOR LEVELING AT MAXIMUM FULL-BAND LEVELED POWER.
***10-DB COUPLER SHOWN APPLIES TO INSTRUMENTS WITH MAXIMUM FULL-BAND LEVELED POWER OF 20 mw. USE LOWER COUPLING VALUE AND/OR INSERT A FLAT PAD BETWEEN THE COUPLER AND DETECTOR FOR PLUG-IN UNITS WITH HIGHER LEVELED OUTPUT POWER. LOCATE THIS COUPLER AS CLOSE AS POSSIBLE TO THE LOAD FOR BEST LEVELING PERFORMANCE.

A. External Leveling with Individual Components



*THE COUPLING VALUE USED MUST SUPPLY AT LEAST 1 mw TO THE INTERNAL DETECTOR WITH THE LEVEL OF OUTPUT POWER TO BE USED. ABOVE 12.4 GHz, USE AN EQUIVALENT WAVEGUIDE COUPLER AND CRYSTAL DETECTOR.

B. Leveling with ALFRED Sampler Located at the Load (1 - 12 GHz Coverage)


ALFRED 6400 SERIES
RF OUTPUT
RF SAMPLER
500 mw MAX (1 - 4 GHz)
200 mw MAX (4 - 8 GHz)
ALFRED MODEL 1151 - 1153 SAMPLER-ATTENUATOR
ADJUSTABLE LEVELED POWER TO LOAD

C. Leveling with ALFRED Model 1151 - 1153 Sampler-Attenuator Located at the Load (1 - 8 Gc Coverage)

Figure 3-10. Typical Connections for External Leveling.

allow higher narrow-band leveling and also provide an additional 5 db reduction range when the control is turned fully counterclockwise, as shown in Figure 3-9. If necessary, adjust the RF SAMPLER SENS panel screwdriver control to provide the proper response for the detector used, to permit full-band leveling at an appropriate position of the POWER LEVEL control. The UNLEVELED light will go off only when power is leveled over the band being swept. Turning the RF SAMPLER SENS control clockwise reduces the sensitivity of the leveler amplifier to the external sampler signal and thereby raises the power level obtained for any setting of the POWER LEVEL control. This has the effect of moving the full-band leveling position of the POWER LEVEL control toward its counterclockwise limit. Turning the RF SAMPLER SENS control counterclockwise increases the sensitivity of the leveler-amplifier to the external sampler signal, and thereby reduces the power level obtained for any setting of the POWER LEVEL control. This has the effect of moving the full-band leveling position of the POWER LEVEL control toward its clockwise limit. If the desired leveling response cannot be obtained with any setting of the RF SAMPLER SENS control, check whether insufficient power is reaching the external sampler detector through the sampling coupler used.

CAUTION

Adjust the RF SAMPLER SENS control with a screwdriver made of plastic or other non-ferrous material, to avoid damage to the microwave tube.

e. Follow Steps c. and d. of Paragraph 3.12.2 above. On 64(*)4 and 64(*)5 Series units, the ATTENUATOR control must originally be set to 0 for maximum power output. Similarly on 64(*)0 Series units with a flap attenuator, the black POWER LEVEL control should initially be turned fully clockwise for maximum power output. On these instruments, set the desired power level using the red POWER LEVEL control. Then for optimum performance, turn the ATTENUATOR control (64(*)4 and 64(*)5) or black POWER LEVEL control (64(*)0) to decrease power until the UNLEVELED light comes on, and then back off until the light goes off again. This provides the desired output level while allowing the tube to operate at maximum leveled power, through use of the built-in attenuator. If more power level reduction than that provided by the red POWER LEVEL control is required, the ATTENUATION control (64(*)4 or 64(*)5) or the black POWER LEVEL control (64(*)0) can be used to obtain it. Note that when such attenuation is used to provide reduction of output level, it will reduce the output of the external leveler sampler since it is now within the rf feedback loop. Therefore, it may become necessary to adjust the RF SAMPLER SENS control to restore the desired leveled condition.

3.12.4 EXTERNAL POWER LEVEL CONTROL AND PROGRAMING. During leveled operation with internal or external sampling, the rf power output level can be controlled over at least a 5 db range below the full-band leveling point on most units by use of a 1 K potentiometer or adjustable resistor network connected to the REMOTE POWER LEVEL banana jacks on the rear panel. The arrangement is shown in Figure 3-3. If the front panel red POWER LEVEL control is turned fully clockwise, the connection to the REMOTE POWER LEVEL jacks will provide output reduction to the full-band leveling point and then at least 5 db additional reduction, as the wiper of a 1 K potentiometer is moved between the MAX and MIN end taps. If the front panel red POWER LEVEL control is turned away from its fully clockwise position, the total control range of the connection to the REMOTE POWER LEVEL jacks will be reduced, since the two circuits are connected in parallel to generate the internal leveling reference signal.

If desired, the output can be reduced to the level where full-band leveling occurs by means of the front panel POWER LEVEL control, and then the REMOTE POWER LEVEL jacks can be used to provide a control range of about 5 db below the full-band leveling point. This arrangement eliminates the need for achieving full-band leveling with the remote connection.

A typical response curve for remote power level control is shown in Figure 3-3. Some units with solid-state leveling provide a control range of more than 5 db below the full-band leveling point, as illustrated. On these units, the full available range may be safely used. On grid-leveled BWO units, do not attempt to reduce leveled power more than 5 db below the minimum unleveled output power.

To use external power level control, follow the leveling procedure given above in Paragraph 3.12.2 or 3.12.3, and adjust the power level in accordance with this Paragraph and Figure 3-3.

3.12.5 ADJUSTMENT OF POWER LEVEL IN UNLEVELED OPERATION (64(*)2, 64(*)3, and 64(*)5 Series). During unleveled operation, the PIN diode leveler attenuator in the rf output circuit is still operative and may be used to adjust the output level. With the RF OUTPUT Selector switch in the UNLEVELED position, the output level may be reduced by at least 5 db from the instantaneous unleveled value by turning the red POWER LEVEL control counterclockwise. Since the tube continues to operate at full power, the attenuated output level is obtained without any frequency shifting effects. On these instruments, this control must be left in the fully clockwise position to obtain maximum unleveled power. On the 64(*)4 Series instruments, the ATTENUATION control may also be used for up to 50 db of power level adjustment.

3.12.6 ADJUSTMENT OF POWER LEVEL IN UNLEVELED OPERATION (64(*)4 Series). During unleveled operation, the red POWER LEVEL control does not function, but the ATTENUATION control may be used for up to 50 db of power level adjustment. Since the tube continues to operate at full power, the attenuated output level is obtained without any frequency shifting effects.

3.12.7 ADJUSTMENT OF POWER LEVEL IN UNLEVELED OPERATION (64(*)0 SERIES ABOVE 12.4 GHz ONLY). During unleveled operation, the flap attenuator in the rf output circuit may be used to adjust the output level. This attenuator is operated by the black POWER LEVEL control knob and will reduce the output level by at least 10 db from the instantaneous unleveled value when turned counterclockwise. Since the tube continues to operate at full power, the attenuated output level is obtained without any frequency shifting effects. On these instruments, this control must be left in the fully clockwise position to obtain maximum unleveled power.

3.13 USE OF MARKERS

3.13.1 INTERNAL RF MARKERS. The internal rf markers can be used only when the rf output is leveled, and appear in the output as an absorptive dip in the output level. This decrease occurs when the output frequency crosses the setting of the M_1, M_2, and F_0 dial indicators in $F_1 \rightarrow F_2$ and manual sweep modes. In $F_0 \pm \Delta F$ sweep mode, only the M_1 and M_2 markers are operative. The amplitude of the marker dip is variable by the MARKER AMPLITUDE control, increasing as it is turned clockwise out of the OFF position. At the maximum setting, just before the switched EXT position, the amplitude is at least 2 db

in the three slower sweep speed ranges, and at least 0.2 db in the fastest sweep speed range. The base width of the markers at miximum amplitude is approximately 0.05% of the full frequency range at all sweep speeds. The base width decreases as the amplitude is decreased. The markers do not appear during retrace if the rf is left on. These markers pips will be found to be even sharper than those obtained with a cavity wavemeter.

3.13.2 EXTERNAL VIDEO MARKERS. The external rf markers are provided for use when the rf output is unleveled, and can be used in the leveled condition as well. These markers are provided to the MARKER OUTPUT jack only when the MARKER AMPLITUDE control is in the EXT switched position. They have an amplitude of about -1 V and a width of about 5 μs. Pulse width is independent of the sweep time used. They can be applied to an oscilloscope display of the detected rf output by summing the signal from the MARKER OUTPUT jack with the detector output at the input to the oscilloscope vertical amplifier, using a BNC tee. It may be necessary to add impedance to either the detector output or video marker lines to match signal levels to obtain the desired presentation. These video markers are not provided during retrace.

The external video markers will be found useful for the following situations:

a. When output is unleveled and rf markers are not available.

b. In reflectometer applications where it is necessary to have a constant drive level to avoid spurious reflections.

c. In measurement applications where level variations in the response swamp out the low-amplitude rf markers.

d. In loss measurements of filters and attenuators where the rf markers are attenuated.

e. In test system applications where it is convenient to have a trigger pulse available when a certain frequency or frequencies are crossed to actuate programmed readout measurements, level changes, etc.

3.14 RF OUTPUT BLANKING DURING SWEEP RETRACE.

During the sweep modes of operation, the rf power can either be on or off during sweep retrace and until the next sweep is triggered. Selection of either of these conditions is provided by the RETRACE switch. In the OFF position, the rf power is turned off during retrace by biasing the microwave tube beyond beam cut-off. Thus, no rf power appears at the RF OUTPUT connector during retrace. This permits zero reference points to be established.

3.15 AUXILIARY OUTPUT SIGNALS.

For convenience in operating the Model 6400 Series with oscilloscope and recorder displays, several auxiliary output signals are supplied. These are discussed individually in the paragraphs below.

3.15.1 OUTPUT SWEEP SIGNAL. This signal is convenient for driving the oscilloscope horizontal channel or the recorder X-axis for display of swept presentations. This signal is available at the front panel OUTPUT SWEEP jack. A fixed +15 V is available from the jack for calibrating the display when the adjacent CALIB button is pressed. the OUTPUT SWEEP signal provided in each mode of operation is tabulated in Table 3-4. The output impedance is 10 K Ω.

Table 3-4. OUTPUT SWEEP Signal Provided for each Operating Mode.

Mode:	OUTPUT SWEEP Signal:
Swept, $F_1 \rightarrow F_2$ or $F_0 \pm \Delta F$	0 to +15 V linear sawtooth regardless of swept frequency band; 0 V at sweep start and +15 V at sweep stop.
Manual Sweep	0 to +15 V level, proportional to output frequency between F_1 and F_2; 0 V at F_1 and +15 V at F_2.
Single-Frequency, M_1, F_0, M_2	DC level between 0 and +15 V, proportional to the position of the output frequency within the linear dial range.
Single-Frequency, F_2	Same as manual sweep; +15 V when MANUAL SWEEP control is switched to F_2.
Single-Frequency, F_1	Grounded (can be used as zero-set reference).
FREQUENCY Mode Selector OFF	DC level between 0 and +15 V, proportional to the setting of the F_0 indicator within the linear dial range.

3.15.2 OUTPUT BLANKING SIGNAL. This signal is convenient for driving the oscilloscope Z-axis to blank the presentation trace during sweep retrace. This signal is provided at the front panel OUTPUT BLANKING jack. It has a level of +50 V during retrace and until the next sweep is triggered, and is at 0 V during the sweep. The +50 V output is also supplied continuously during manual sweep, in all single-frequency modes, and when the rf output is turned OFF with the FREQUENCY Mode Selector switch. Output impedance is approximately 10 K ohms.

3.15.3 BLANKING (PEN LIFT) RELAY CONTACTS. A set of form C relay contacts is brought out to the red BLANKING RELAY CONTACT OUTPUT banana jacks on the rear panel. The center jack is common, and the normally-open (N.O.) and normally-closed (N.C.) contact jacks are labeled. This relay is energized whenever the +50 V OUTPUT BLANKING SIGNAL is supplied (see above) if the switch above the BLANKING RELAY CONTACT OUTPUT jacks is in the ON position. When this switch is in the OFF position, the relay can never be energized. Thus, if the jacks are connected to lift a recorder pen or blank a scope trace during retrace, the adjacent switch can be turned OFF to disable the blanking or pen lift when switching temporarily to single-frequency or manual sweep operation. Because of physical response limitations of the relay, it does not operate on the two fastest sweep ranges.

3.16 REMOTE CONTROL AND PROGRAMMING.

To permit incorporation of the Model 6400 Series into automated, programmed test systems, all major functions that cannot be conveniently preset with the panel controls are remotely programmable. These functions are tabulated below, with reference to a previous paragraph for details.

a. Frequency Programming: Any desired sweep start frequency and sweep bandwidth can be programmed and controlled externally. For control with voltages in the 0 to +15 V range, see Paragraph 3.11.1. For control with passive resistance networks, see Paragraph 3.11.2.

b. Amplitude Programming: Any desired amplitude level from full-on to full-off can be programmed and controlled externally. For full-range control with voltages in the 0 to +10 V range, see Paragraph 3.10.2. For control within a 5 db range using passive resistance networks in leveled operation, see Paragraph 3.10.3.

c. Power Level Programming: With internal leveling or external leveling, with a fixed-response sampler, the power level can be remotely programmed and controlled within a 5 db range using passive resistance networks. With an external sampler-attenuator, the control range can be increased. See Paragraph 3.12.

d. Sweep Recurrence Programming: Sweeps can be externally triggered at any desired recurrence rate, with a 5 V signal. See Paragraph 3.8.

3.17 APPLICATIONS INFORMATION.

3.17.1 GENERAL. The following paragraphs indicate typical test set-ups which are useful for basic swept-frequency test applications of the Model 6400 Series. Included are procedures for measurement of the most commonly tested microwave parameters, including reflection coefficient, VSWR, and transmission gain or loss. Most of these set-ups can be used for single-frequency testing as well.

3.17.2 READOUT DISPLAY TECHNIQUES.

3.17.2.1 OSCILLOSCOPE READOUT DISPLAY. The fastest sweep speeds provided by the Model 6400 are ideal for flicker-free oscillographic display for visual inspection and for making permanent records with an oscilloscope camera. A suitable fast-responding detector, such as the ALFRED Model 1001, must be used to properly drive the oscilloscope. The continuous, real time display of a broad swept-frequency range on the oscilloscope CRT permits instantaneous "quick-look" evaluation of performance throughout the band of interest. It also allows real-time monitoring of the effects of adjustments on the device under test.

A wide variety of oscilloscopes can be used for swept-frequency performance measurements. A low-frequency oscilloscope having a vertical bandwidth of 300 KHz or more and dc-coupled vertical and horizontal input channels is adequate. Depending on test power levels and detector characteristics, it may be necessary to use an oscilloscope with high-gain vertical sensitivity. The ALFRED Model 1001 Crystal Detector provides more than 0.5 millivolts per microwatt at low levels, with square-law performance accurate to ± 0.5 db, thus providing an output of 5 millivolts at -20 dbm. The ALFRED RF Samplers offer similar response over their individual frequency ranges. An oscilloscope vertical sensitivity of 1 mv/cm will thus be satisfactory for many applications, but for low-VSWR reflection coefficient measurements and operation with less sensitive detectors, it will be useful to have an oscilloscope with vertical sensitivity of 100 μv/cm.

While the horizontal sweep of the oscilloscope and the frequency sweep of the Model 6400 can be individually synchronized to the line or to some external timing signal, it will usually be preferable to use the Model 6400 OUTPUT SWEEP signal to drive the horizontal deflection channel of the oscilloscope. This 0 to +15 V sweep signal provides an accurate frequency axis for the swept display. If the Model 6400 RETRACE switch is placed in the OFF position, the oscilloscope display will automatically retrace on the zero reference line, providing a continuous zero-power reference trace in recurrent-sweep modes. When the rf is left on during retrace, or when the +50 V BLANKING OUTPUT signal is used to blank the CRT during retrace, it will be convenient to set the zero-power position of the trace to coincide with a graticule line for reference.

For certain applications, it is possible to pre-calibrate the oscilloscope CRT face with a transparent overlay or tick markings so that the familiar "grease pencil" reference calibration traces need not be made. This technique is covered in detail below. It takes advantage of the fact that if the "full power" and "no power" traces are adjusted to a pre-selected deflection, intermediate response in a flat system will appear at vertical intercepts which can be calculated and labeled in advance. This provides pre-calibration for loss and reflection coefficient measurements. It can be extended to gain measurements by coordinating the calibration markings with vertical amplifier attenuator settings. For accuracy, this technique requires use of external leveling with the sampling coupler located at the load; test power levels that allow the output response crystal detector to operate in its square law range; and maximally flat couplers and attenuators outside the leveled loop.

In other applications, where power is unleveled or where components are not flat, the test system can be calibrated in the conventional way, by using an accurate variable attenuator to duplicate the loss or offset the gain of the device under test.

3.17.2.2 RECORDER READOUT DISPLAY. The slower sweep speeds provided by the Model 6400 are ideal for driving X-Y recorders to make a permanent graphic record of swept-frequency test performance. Virtually any recorder with sensitivity of 0.5 mv/in. will be satisfactory for most applications, when the ALFRED Model 1001 Crystal Detector is used. For low-VSWR reflection coefficient measurements and operation with less sensitive detectors, it will be useful to have a recorder with 0.1 mv/in. sensitivity. The graph limits should be set up by adjusting the recorder controls with the pen lifted. Then a single, manually triggered sweep can be used to obtain the test record.

The Model 6400 OUTPUT SWEEP signal is ideal for driving the X-axis of the recorder. This 0 to +15 V sweep signal provides an accurate frequency axis for the swept display. If the Model 6400 RETRACE switch is placed in the OFF position, the graph will automatically retrace on the zero reference line. If the rf is left on during retrace, the BLANKING RELAY CONTACT output terminals on the rear of the Model 6400 can be used to lift the recorder pen automatically during retrace on either of the two slowest sweep ranges. For faithful reproduction of discontinuities in the test response, one of the manual sweep modes may be used to drive the recorder slowly through the point of interest. Manual sweep is also useful for operating recorders without automatic pen controls.

3.17.2.3 METER READOUT DISPLAY. The 100-second sweep speed, selected by turning the SWEEP TIME VERNIER control fully counterclockwise in the 10-second SWEEP TIME Selector switch position, can be used for driving displays in which the readout device is a meter. This sweep speed provides responses within the response capabilities of most meters. Swept-frequency measurements of reflection coefficient, VSWR, noise figure, and power levels can thus be made with direct-reading meters. The internal 1000 Hz square-wave modulation can be used with meters which require audio modulation of the rf signal, including most VSWR and ratio meters. Manual sweep can be used to investigate points of rapid variation.

3.17.3 REFLECTOMETER TECHNIQUES FOR VSWR MEASUREMENT WITH FLAT, PRE-CALIBRATED DISPLAY. (See Figure 3-11.)

3.17.3.1 GENERAL DATA. Reflectometer test systems measure the reflection coefficient of a load by separating the reflected wave propagated in the source-to-load line from the incident power. If the incident power is leveled at the load by use of an external sampling coupler located at the load, the incident power will remain constant over the test band. A single directional coupler can then be used to measure the reflected power variations due to load mismatch.

A typical set-up is shown in Figure 3-11. An attenuator pad can be used at the output of the Model 6400, if necessary to reduce the level to the values shown. The 10-db couplers or samplers used for sampling incident power for the leveler and for sampling reflected power for readout should be matched as closely as possible (and preferable should be maximally flat). The test arrangement shown in Figure 3-11 will compensate for non-flat performance of the couplers if they are matched. This is because the leveling in accordance with the curve of the first coupler will then produce a power level across the band that provides constant output from the second coupler.

To test waveguide systems below 12.4 GHz, place a coax-to-waveguide adapter at the output of the Model 6400 and at the input to the detectors, unless waveguide crystal detector mounts are used. This permits use of more accurate high-directivity waveguide directional couplers. Attenuator pads, filters, and adapters placed between the Model 6400 RF OUTPUT connector and the external leveling sampler will not degrade the leveling performance, provided sufficient power is supplied to the leveler detector to generate a drive of -100 mv at the point of minimum unleveled output. The level must be kept within the square-law range of the reflected power detector, if a pre-calibrated display is to be used without individual calibration using a variable attenuator. The level must be kept within the square-law range of both detectors if automatic compensation for non-flat couplers is to be obtained. Otherwise, i.e. with flat couplers, the power level applied to the leveler sampler detector can exceed the square-law range.

The reflectometer technique theoretically has excellent accuracy over a wide VSWR range. The accuracy of a VSWR measurement of 1.22 is typically ± 0.05. The lowest VSWR that can be accurately measured is limited by the directivity of the reflected power readout coupler. Low-directivity couplers permit combination of a small amount of incident power with the reflection readout line. This can be enough to produce inaccuracy when the reflection level is low. Thus, measurement of low VSWR ratios requires high-directivity couplers. For reflectometer measurements of a VSWR as low as 1.10, coupler directivity should be 30 db or greater; for a VSWR of 1.05, coupler directivity should be 35 db; for a VSWR of 1.03, coupler directivity should be 40 db. The measurement of large VSWR ratios is limited by the directivity of the incident power sampling coupler.

The procedure given below provides for measurements which are calibrated to a direct-reading tick-mark scale located at any convenient point on the CRT graticule or recorder graph paper. Flat, leveled performance across the band eliminates the need for recording full-width calibration traces.

3.17.3.2 DETAILED PROCEDURE. To calibrate the oscilloscope or recorder and carry out VSWR measurements, set up equipment as shown in Figure 3-11 and proceed as follows:

a. Adjust the Model 6400 controls to establish the desired sweep mode and external leveling.

b. Turn the MODULATION Selector switch to AM EXT to turn off the rf output while maintaining the OUTPUT SWEEP signal.

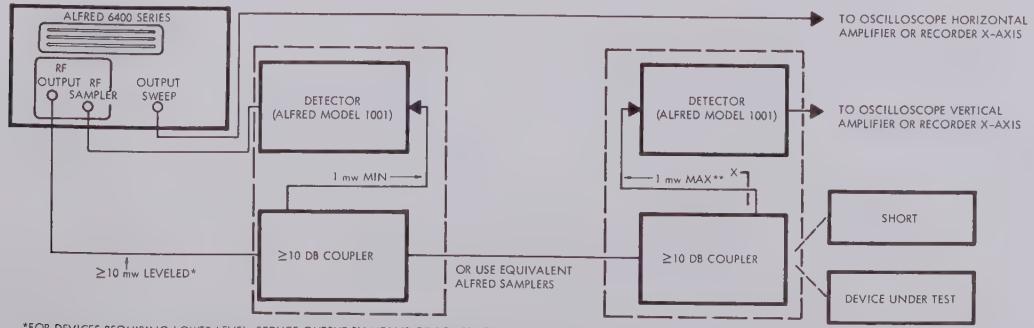
c. Adjust the oscilloscope or recorder horizontal gain control to obtain the desired calibration in GHz per cm or GHz per inch from the Model 6400 OUTPUT SWEEP drive signal.

d Adjust the oscilloscope vertical offset controls to place the trace on the lowest horizontal line of the graticule (3 cm from center on a standard 6-cm scope). Adjust the recorder zero position as necessary to place the pen over the bottom line on the graph. This line corresponds to zero reflection (infinite return loss), which can be calibrated as 1.00 on a direct-reading VSWR scale on the CRT face or recorder chart paper.

NOTE: Detector output connections should be made with proper polarity to provide up-scale deflection on the oscilloscope or recorder.

e. Place a 100% short on the output end of the readout coupler.

f. Turn the MODULATION Selector switch to AM OFF and check for leveled output by observing that the UNLEVELED light is not lit. Adjust the oscilloscope or recorder vertical attenuator and calibration vernier controls as required to place the trace on the top line of the graticule or graph paper. Do not readjust the zero position controls. If the detected output level is above the square-law range of the detector used, reduce the Model 6400 output power with



*FOR DEVICES REQUIRING LOWER LEVEL, REDUCE OUTPUT BY MEANS OF POWER LEVEL CONTROL OR ADD A FLAT PAD BETWEEN THE TWO COUPLERS
**DO NOT EXCEED THE SQUARE-LAW RANGE OF THE DETECTOR CRYSTAL WHICH DRIVES THE OSCILLOSCOPE. (ALFRED DETECTORS GIVE SQUARE-LAW PERFORMANCE WITHIN ± 0.5 DB UP TO ABOUT 1 mw.) ABOVE 12.4 GHz USE A SUITABLE ALTERNATE DETECTOR OR SAMPLER.
X - FOR CALIBRATION OF INDIVIDUAL TEST SET-UPS, INSERT A PRECISION VARIABLE ATTENUATOR AT POINT X.

Figure 3-11. Reflection Coefficient (VSWR) Measurements Using Calibrated Oscilloscope or Recorder.

the POWER LEVEL control. The line now being traced represents 100% reflection or 0 db return loss, which can be calibrated as ∞ on a direct-reading VSWR scale on the CRT face or recorder chart paper.

g. Remove the reflectometer short installed in Step e. above and observe the display with the output open-circuited. Approximately the same deflection should be obtained, since the open circuit discontinuity reflects most of the power with a minimum of transmission. If the deviation from full-scale deflection is within ± 10%, adjust the vertical amplifier vernier control halfway between the settings that place the "short" and "open" ∞ VSWR reference line on the desired scale division. If substantial difference exists between these two calibration lines, investigate the source of error in the measurement system, which may be a low-directivity coupler.

h. The direct-reading VSWR scale may now be calibrated for the full range of VSWR from 1 to ∞ by using a slide rule, a ruler or scale calibrated in divisions of the unit spacing on the CRT graticule or recorder graph paper, and the following equations:

(1) Reflection coefficient equation:

$$\rho = \frac{E \text{ reflected}}{E \text{ incident}} = \frac{VSWR - 1}{VSWR + 1}$$

$$= \sqrt{\frac{P \text{ reflected}}{P \text{ incident}}} \text{ as measured with voltage signals from a square-law detector.}$$

(2) VSWR equation:

$$VSWR = \frac{1 + \rho}{1 - \rho}$$

where VSWR = ratio of the maximum to minimum voltage in the standing wave along the transmission line; ρ = magnitude of the reflection coefficient; $-20 \log \rho$ = definition of return loss.

Example A

Calibrate the vertical center point of the 1.00-to-∞ VSWR display:

At the center point, the detector output signal is 1/2 that at full reflection. Since the trace made with full reflection corresponds to the incident power level, the reflected signal which gives a center-scale deflection has 1/2 the power of the incident wave because square-law detector readings are directly proportional to power. From equation (1) above,

$$\sqrt{0.5} = \rho = 0.707$$

from equation (2),

$$VSWR = \frac{1.707}{.293} = 5.83$$

Example B

Similarly, for a 6-unit scale such as a standard 6-cm CRT graticule, the divisional calibration points between 1.00 and ∞ can be calculated as 2.38, 3.73, 5.83, 9.9, and 22.

i. If the VSWR is below 2.0, it will be convenient to increase the vertical amplification of the oscilloscope or recorder by a factor of 10 or more, to increase the sensitivity of the direct-reading display. The scale must then be re-calibrated since the ∞ VSWR line which represents incident power is effectively moved off-scale by an amount equal to the full-scale deflection times the change in amplification. The 1.00 VSWR line remains unchanged and the display is effectively expanded.

Example A

Calculate the new VSWR values to calibrate the half-scale and full-scale VSWR lines when input amplification is increased by 10:1.

At full scale deflection, since the ∞ VSWR line (which represents incident power) has been moved a distance of 10 scale amplitudes above the scale, the reflected wave has 1/10 the power of the incident wave. From equation (1),

$$\rho = \sqrt{\frac{1}{10}} = 0.316$$

From equation (2)

$$VSWR = \frac{1.316}{.684} = 1.93$$

Similarly, at half scale, the reflected wave has 1/20 the power of the incident wave and

$$\rho = \sqrt{\frac{1}{20}} = 0.229$$

$$VSWR = 1.59$$

Example B

Similarly, for 10:1, 20:1, 50:1, and 100:1 amplification increases, the scale divisions for a 6-unit scale will be tabulated below:

Amplification	10:1	20:1	50:1	100:1
VSWR	1.00	1.00	1.00	1.00
	1.30	1.20	1.12	1.085
	1.45	1.30	1.18	1.122
	1.58	1.38	1.22	1.152
	1.70	1.45	1.26	1.18
	1.81	1.51	1.30	1.20
	1.93	1.58	1.33	1.22

j. Connect the device under test to the output end of the readout coupler. Without changing the zero or calibration vernier adjustments previously set to calibrate the trace, switch to the vertical channel amplification step that brings the trace closest to full-scale deflection. Then select the precalibrated scale corresponding to the amplification setting used and read the VSWR directly from the display.

k. Obtain recorder plots or oscilloscope photos for permanent record as desired.

l. Repeat Steps j. and k. for all devices to be tested.

3.17.4 REFLECTOMETER TECHNIQUES FOR VSWR MEASUREMENT WITHOUT FLAT DISPLAY. (See Figure 3-11.)

3.17.4.1 GENERAL DATA. In some test situations, it will not be possible to use the flat, tick-mark-calibrated readout display method outlined above. These situations include set-ups where the reflected power detector must be operated above square-law level, where a non-flat pad must be used to reduce the power level outside the leveled loop, where the

leveler sampling coupler cannot be located next to the reflectometer output coupler for true incident power leveling, or where internal leveling is used.

In such cases, a variable precision attenuator can be inserted into the system between the reflectometer output coupler and the reflected power detector to calibrate the system. Usually, calibration lines the full width of the display will be required to calibrate the display because of level variations across the band. These can be traced in grease-pencil on a CRT graticule overlay, or recorded in a contrasting color on the X-Y recorder graph.

For this test method, use the test set-up shown in Figure 3-11 except that external leveling is optional, and the attenuator must be added at point X. Refer to the text discussion in Paragraph 3.17.3.1 for additional data on the reflectometer instrumentation technique. Follow the procedure given below.

3.17.4.2 DETAILED PROCEDURE. To calibrate the oscilloscope or recorder and carry out VSWR measurements, proceed as follows:

a. Follow Steps a through e of 3.17.3.2 with changes as required by the differences in test set-up used.

b. Turn the precision variable attenuator at point X to 0 db.

c. Turn the MODULATION Selector switch to AM OFF and check for leveled output by observing that the UNLEVELED light is not lit.

d. To make an individual measurement, connect the device under test to the output end of the readout coupler. Adjust the oscilloscope or recorder controls to obtain a performance trace at near-full-scale deflection. Note this trace on the display. Then, without adjusting the display controls, substitute the 100% short and adjust the precision variable attenuator to produce a calibration trace which intersects the performance trace. Several settings of the precision variable attenuator may be required to calibrate the performance trace at different points of intersection, depending upon the variation of VSWR over the band tested. The db readings obtained from the precision variable attenuator can be read directly as "return loss," which equals $-20 \log_{10} \rho$. These readings can thus be converted to ρ and then to VSWR.

Example A

The precision attenuator reading at one point of intersection between the performance and calibration traces is 26 db. Calculate the VSWR:

From Equation (2) under Step h. of 3.17.3.2 above,

$$26 = 20 \log_{10} \rho$$

$$\log_{10} \rho = \frac{-26}{20} = -1.3$$

$$\rho = 10^{-1.3} = 0.05$$

$$\text{VSWR} = \frac{1.05}{.95} = 1.1$$

Example B

Other values can be calculated as above or found in standard microwave reference handbooks.

e. To calibrate the display for a series of measurements using the precision variable attenuator, several calibration traces as above can be made for various attenuator settings with the reflectometer output shorted. If a different setting of the recorder or oscilloscope input amplifier is required to bring the trace into position when a device is tested, the db equivalent of that amplification change must be added to the "return loss" value in computing equivalent VSWR. If the crystal is operating in its square-law range, the db equivalent of the amplification change is 10 times the $\log_{10}$ of the voltage amplification added. For optimum results, and particularly if there is any doubt as to crystal performance, run calibration traces at the same amplification setting that gives on-scale readout with the device under test.

f. Obtain recorder plots or oscilloscope photos for permanent record as desired.

g. Repeat Steps d or e and f for all devices to be tested.

3.17.5 BASIC TECHNIQUE FOR MEASUREMENT OF GAIN AND LOSS. (See Figure 3-12.)

3.17.5.1 GENERAL DATA. The basic test set-up tor measurement of gain and loss can be used for gain vs. frequency measurements, loss vs. frequency measurements, dynamic range measurements, stability measurements, or for measurements of a controlled gain or loss parameter vs. the control parameter. A typical set-up, which can be modified to suit an individual situation, is shown in Figure 3-12.

The precision variable attenuator permits exact calibration of the gain or loss performance in db, and allows reduction of the input level to the equipment under test, if required by its sensitivity range. The pad attenuator at the output of the equipment under test minimizes output reflections.

For loss measurements where the output level obtained from the equipment under test is much below -20 dbm, it is often advantageous to use a low-noise TWT amplifier, such as an instrument of the ALFRED 5000 Series, to raise the level to the sensitivity range of standard detectors. For gain measurements, to avoid exceeding the maximum power dissipation of the detector, the precision variable attenuator can be used to reduce the input signal level at the equipment under test, or a larger attenuator can be connected to the equipment output. Use the technique which best suits the sensitivity and performance ranges of the equipment under test. The detected output can be applied either to an oscilloscope or recorder Y-axis, or to a meter.

3.17.5.2 DETAILED PROCEDURE. To make gain or loss measurements using the general set-up of Figure 3-12, a typical procedure is as follows:

a. Refer to Figure 3-12 and make rough calculations of necessary pad attenuator values and/or the minimum setting of the precision attenuator to assure that permissible power levels will not be exceeded, either at the equipment under test or at the detector. Determine whether additional pre-detection amplification will be required. Complete the test set-up, making necessary modifications from the typical arrangement shown in Figure 3-12 and setting the attenuator level(s).

b. Adjust the Model 6400 controls to establish the desired sweep and leveling mode.

c. Turn the MODULATION Selector switch to AM EXT to turn off the rf output while maintaining the OUTPUT SWEEP signal.

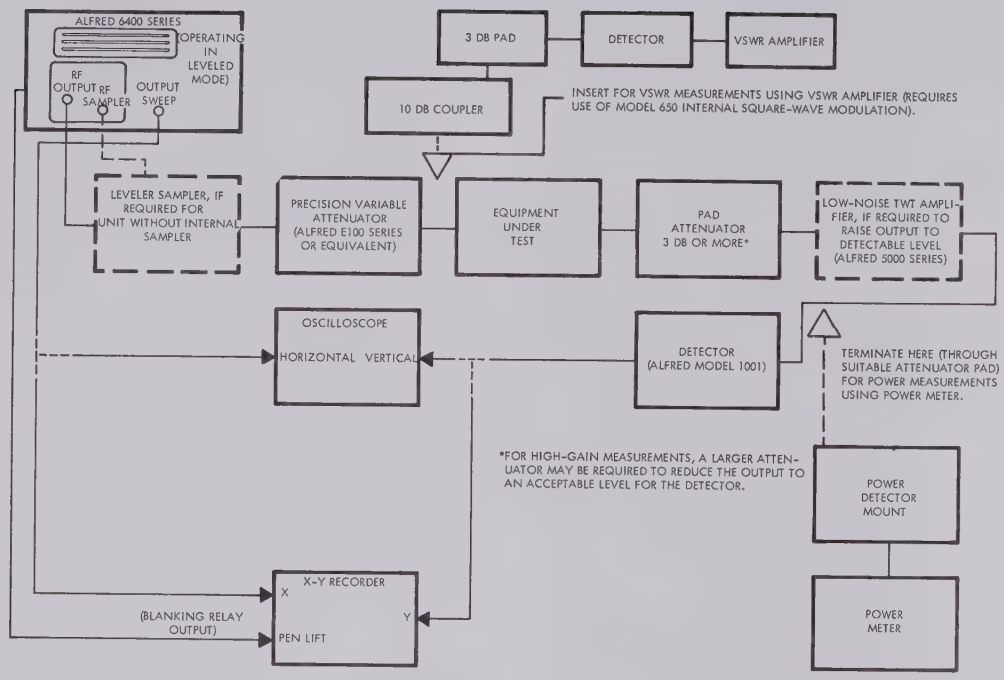

ALFRED 6400 SERIES
OPERATING IN LEVELED MODE)
RF OUTPUT
RF SAMPLER
OUTPUT SWEEP
3 DB PAD
DETECTOR
VSWR AMPLIFIER
10 DB COUPLER
INSERT FOR VSWR MEASUREMENTS USING VSWR AMPLIFIER (REQUIRES USE OF MODEL 650 INTERNAL SQUARE-WAVE MODULATION).
LEVELER SAMPLER, IF REQUIRED FOR UNIT WITHOUT INTERNAL SAMPLER
PRECISION VARIABLE ATTENUATOR (ALFRED E100 SERIES OR EQUIVALENT)
EQUIPMENT UNDER TEST
PAD ATTENUATOR 3 DB OR MORE*
LOW-NOISE TWT AMPLIFIER, IF REQUIRED TO RAISE OUTPUT TO DETECTABLE LEVEL (ALFRED 5000 SERIES)
OSCILLOSCOPE
HORIZONTAL VERTICAL
DETECTOR (ALFRED MODEL 1001)
TERMINATE HERE (THROUGH SUITABLE ATTENUATOR PAD) FOR POWER MEASUREMENTS USING POWER METER.
*FOR HIGH-GAIN MEASUREMENTS, A LARGER ATTENUATOR MAY BE REQUIRED TO REDUCE THE OUTPUT TO AN ACCEPTABLE LEVEL FOR THE DETECTOR.
POWER DETECTOR MOUNT
X-Y RECORDER
X
Y
(BLANKING RELAY OUTPUT)
PEN LIFT
POWER METER

Figure 3-12. General-Purpose Test Set-Up for Swept or Single-Frequency Measurements

d. Adjust the oscilloscope or recorder horizontal gain control to obtain the desired calibration in GHz per cm or GHz per inch.

e. Turn the MODULATION Selector switch to AM OFF to supply rf output. Adjust the recorder or oscilloscope vertical controls as necessary to obtain a good presentation. Then record a single performance trace on the recorder, or preserve the oscilloscope performance trace with a grease-pencil mark. Note the precision attenuator setting at which the trace is obtained. (If measurement of dynamic range is desired, make additional trace measurements with different settings of the precision attenuator, and note both these attenuator settings and the gain settings of the recorder or oscilloscope. If the latter must be changed, make changes only in the calibrated step amplification settings, not in the vernier.)

f. Remove the equipment under test from the test circuit, connecting the precision variable attenuator directly to the equipment output pad attenuator.

g. Without adjusting the oscilloscope or recorder controls, change the setting of the precision attenuator to produce a calibration trace which intersects the previously-recorded performance trace. Record several calibration traces, with different settings of the precision attenuator to calibrate the performance trace at various points of intersection. The points of intersection of each calibration trace with the previously-recorded performance trace will calibrate that trace in db. The difference in db between the precision attenuator setting of each calibration trace, and that used for recording the performance trace, is the absolute db value of performance for each point of intersection. Interpolation can be used between calibration traces. If several performance traces were made using different display gain settings, obtain additional calibration traces for those gain settings, or correct the existing calibration traces for those conditions, by taking into account the db value of the amplification change: The gain increment in db = 10 $\log_{10}$ (amplification decrease) when the crystal is in its square law range.

h. Obtain recorder plots or oscilloscope photos for permanent record as desired.

i. Repeat Steps e through h for all devices to be tested.

3.17.6 TECHNIQUE FOR TRANSMISSION MEASUREMENTS WITH FLAT, PRE-CALIBRATED DISPLAY (See Figures 3-18 and 3-14).

3.17.6.1 GENERAL DATA. A technique similar to that discussed in Paragraph 3.17.3 can be used for gain or loss measurement by comparing the incident and transmitted power levels. If the incident power is leveled at the load by use of an external sampling coupler located at the load, the incident power will remain constant over the test band. A single sampler or a detector connected directly to the device output, depending upon output level, can then be used to measure the transmitted power. In some test situations, it will not be possible to use a flat, tick-mark-calibrated readout display method outlined here, and the general procedure given in Paragraph 3.17.5 must be used. These situations include cases where high VSWR exists or where significant phase shift changes take place across the band with moderate VSWR; where the transmitted power detector must be operated above square-law level; where the output power cannot be leveled at the load or where a non-flat pad must be used to reduce the power level outside the leveled loop; and where non-flat couplers are used and the leveler sampler detector must operate above square-law range, thereby preventing automatic coupler compensation.

General test set-ups for loss measurements are shown in Figure 3-13, and a general set-up for gain measurement is shown in Figure 3-14. The basic test circuit is similar to that shown in Figure 3-11 for reflectometer measurements, except that the equipment under test is placed between the two couplers. Note that in the test set-ups shown in Figures 3-13 and 3-14, the operating power levels are kept within the square-law range of ALFRED Model 1001 Detectors. A pad attenuator can be used at the output of the Model 6400 as necessary to reduce the level to the values shown. It is preferable to use maximally flat samplers or couplers, but the test circuits shown in Figures 3-13A and 3-14 will compensate for variations in coupler response across the band if matched couplers are used.

In Figure 3-13A, where the incident power sampling coupler and the output power sampling coupler are of identical value, the use of matched couplers with detectors in the square-law range will allow the couplers to compensate for each other. For greatest accuracy, the couplers used should have high directivity. In testing waveguide systems below 12.4 GHz, place a coax-to-waveguide adapter at the output of the Model 6400 and at the input to the detectors, unless waveguide crystal detector mounts are used. This permits use of more accurate high-directivity waveguide directional couplers.

In Set-ups where the detector is connected directly to the output of the equipment under test, or where different coupling values must be used to obtain workable power levels at the input and output, maximally-flat samplers or couplers must be used. Figure 3-14 shows how a maximally-flat coupler can be simulated for the leveler sampler loop by using two identical matched 3-db couplers in tandem. The detector arm of the first coupler is connected through the primary path of an identical matched coupler whose secondary terminal is terminated in a load. This technique does not apply to couplers of other values, however, unless they are specifically designed to provide matched compensation at different power levels.

Note that if an output coupler is used for gain tests it is not usually possible to use identical matched couplers for input and output power sampling because the power supplied to the leveler detector under such conditions would not provide sufficient output for leveling. Because of phase considerations in the leveling loop, it is not possible to add dc amplification between the leveler detector output and the RF SAMPLER INPUT jack. The maximum permissible gain in the leveling loop is that obtained when the RF SAMPLER SENS control is turned fully CCW. Thus, in gain tests where flat pads or flat couplers are not available, and in other test situations where matched couplers are not available, it may be preferable to use the general procedure with a precision variable attenuator for calibration of non-flat response, as given in Paragraph 3.17.5.

The procedures given below provide for loss and gain measurements which are calibrated to a direct-reading tick-mark scale located at any convenient point on the CRT graticule or recorder graph paper. Subject to the limitations discussed above, flat, leveled performance across the band eliminates the need for recording full-width calibration traces.

3.17.6.2 LOSS MEASUREMENT PROCEDURE. To calibrate the oscilloscope or recorder and carry out loss measurements, set up equipment as shown in Figure 3-13, and proceed as follows:

a. Adjust the Model 6400 controls to establish the desired sweep mode and external leveling.

b. Turn the MODULATION Selector switch to AM EXT to turn off the rf output while maintaining the OUTPUT SWEEP signal.

c. Adjust the oscilloscope or recorder horizontal gain control to obtain the desired calibration in GHz per cm or GHz per inch, from the Model 6400 OUTPUT SWEEP drive signal.

d. Adjust the oscilloscope vertical offset controls to place the trace on the lowest horizontal line of the graticule (3 cm from center on a standard 6-cm scope). Adjust the recorder zero position as necessary to place the pen over the bottom line on the graph. This line corresponds to infinite attenuation (zero signal), which can be calibrated as ∞ on a direct reading scale of loss.

e. NOTE: Detector output connections should be made to allow up-scale deflection on the oscilloscope or recorder.

e. In the circuit of Figure 3-13A, connect the input and output sampling couplers together at the point where the device under test would normally be inserted. In the circuit of Figure 3-13B, connect the output detector (and pad, if used) directly to the input sampling coupler, bypassing the device under test.

f. Turn the MODULATION Selector switch to AM ON and check for leveled output by observing that the UNLEVELED light is not lit. Adjust the oscilloscope or recorder vertical attenuator and calibration vernier controls as required to place the trace on the top line of the graticule or graph paper. Do not readjust the zero position controls. If the detected output level is above the square-law range of the detector used, reduce the Model 6400 output power with the POWER LEVEL control.

   The line now being traced represents zero attenuation (full-strength signal). It can be calibrated as 0 db on a direct-reading attenuation scale on the CRT face or recorder chart paper.

g. The direct-reading attenuation scale may now be calibrated for the full range of attenuation from 0 db to ∞ by using a slide rule, a ruler or scale calibrated in divisions of the unit spacing on the CRT graticule or recorder graph paper, and the following equation:

   (1) Definition of db ratios:

$$\frac{E_1}{E_2}\ \text{db} = 20 \log \frac{E_1}{E_2}$$

$$= 10 \log \frac{P_1}{P_2}$$ as measured with voltage signal from a square-law detector.

Example A

Calibrate the vertical center point of the 0 db to ∞ attenuation scale:

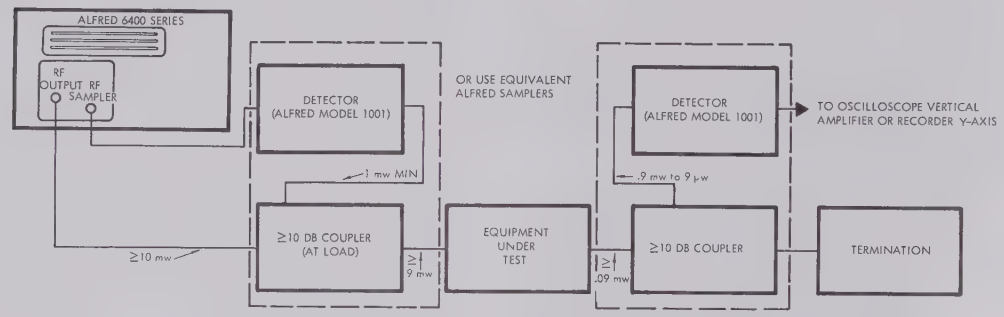
At the center point, the detector output signal is one-half that at the "0 db" point. Since the 0 db trace corresponds to the incident power level, the output signal which gives a center-scale deflection has one-half the power of the incident wave because square-law detector readings are directly proportional to power. From equation (1) above,

$$\text{db} = 10 \log \frac{2}{1} = 3 \text{ db}$$

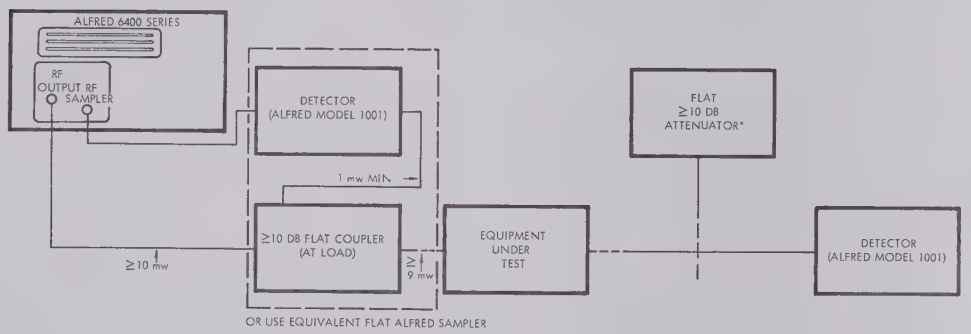
Example B

Similarly, for a 6-unit scale such as a standard 6-cm CRT graticule, the divisional calibration points between 0 and ∞ can be calculated as 0.8 db, 1.8 db, 3.0 db, 4.8 db, and 7.8 db.

h. If the loss is more than 10 db, it will be convenient to increase the vertical amplification of the oscilloscope or recorder by a factor of 10 or more to increase the sensitivity of the direct-reading display. The db value of the amplification increase must be added to the loss read directly from the calibrated scale. If the output detector crystal is operating in its square-law range, the db value is 10 times the $\log_{10}$ of the voltage amplification added: 10:1 = 10 db; 20:1 = 13 db; 50:1 = 17 db; 100:1 = 20 db. With these db values added, the scale can be read directly as previously calibrated.



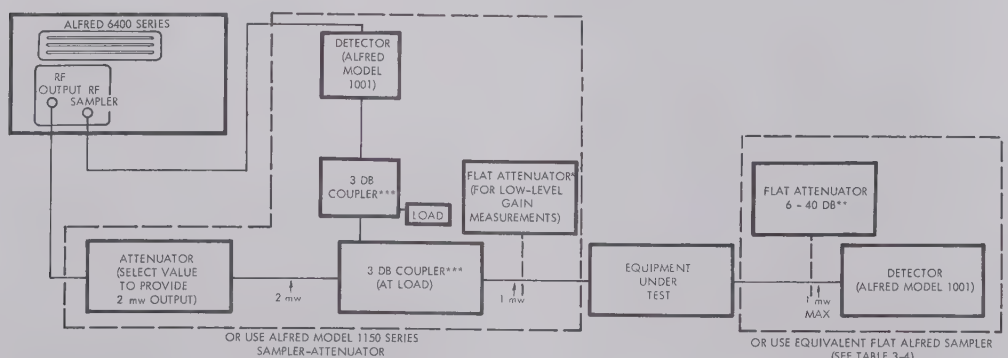
A. Measurement of 0 - 20 db Loss with Matched Coupiers



*INSERT FOR SETTING NO-LOSS REFERENCE LINE, AND FOR MEASUREMENT OF LOSSES LESS THAN 10 DB, TO AVOID EXCEEDING SQUARE-LAW RANGE OF DETECTOR; OR USE EQUIVALENT FLAT ALFRED SAMPLER WITH TERMINATION INSTEAD OF ATTENUATOR-DETECTOR COMBINATION, AND A SEPARATE MODEL 1001 DETECTOR WHEN ATTENUATION IS NOT NEEDED. TO MEASURE LOSS >40 DB, USE HIGHER RF POWER AND CORRESPONDINGLY GREATER CALIBRATION ATTENUATION.

B. Measurement of Loss with Flat Components

Figure 3-13. Transmission Loss Measurements Using Calibrated Oscilloscope or Recorder.


ALFRED 6400 SERIES
RF OUTPUT RF SAMPLER
DETECTOR (ALFRED MODEL 1001)
3 DB COUPLER***
LOAD
FLAT ATTENUATOR* (FOR LOW-LEVEL GAIN MEASUREMENTS)
FLAT ATTENUATOR 6 - 40 DB**
ATTENUATOR (SELECT VALUE TO PROVIDE 2 mw OUTPUT)
2 mw
3 DB COUPLER*** (AT LOAD)
1 mw
EQUIPMENT UNDER TEST
1 mw MAX
DETECTOR (ALFRED MODEL 1001)
OR USE ALFRED MODEL 1150 SERIES SAMPLER-ATTENUATOR
OR USE EQUIVALENT FLAT ALFRED SAMPLER (SEE TABLE 3-4)

*SET-UP SHOWN PROVIDES FOR 0 DBM MEASUREMENTS. FOR LOW-LEVEL GAIN MEASUREMENTS, INSERT A FLAT PAD ATTENUATOR AT THE LOAD INPUT TO REDUCE THE LEVEL TO THE DESIRED VALUE, OR USE ALFRED MODEL 1150 SERIES SAMPLER-ATTENUATOR.
**INSERT SUITABLE ATTENUATOR TO AVOID EXCEEDING SQUARE-LAW RANGE OF DETECTOR.
***TANDEM CONNECTION OF MATCHED 3 DB COUPLERS SIMULATES FLAT COUPLER.

Figure 3-14. Transmission Gain Measurements Using Calibrated Oscilloscope or Recorder

i. Connect the device under test between the input and output couplers as shown in Figure 3-13. Without changing the zero or calibration vernier adjustments previously set to calibrate the trace, read the attenuation from the calibrated scale. If necessary, switch to another vertical channel amplification step that brings the trace closest to full-scale deflection. Then add the db value of the added amplification to the scale reading as directed in Step h.

j. Obtain recorder plots or oscilloscope photos for permanent record as desired.

k. Repeat Steps i and j for all devices to be tested.

3.17.6.3 GAIN MEASUREMENT PROCEDURE. To calibrate the oscilloscope or recorder and carry out gain measurements, set up equipment as shown in Figure 3-14, and proceed as follows:

a. Follow Steps a through c under Paragraph 3.17.6.2.

b. Follow Steps d through f under Paragraph 3.17.6.2, except in Step f adjust the oscilloscope or recorder vertical attenuator and calibration vernier controls as required to place the trace on the CENTER line of the graticule or graph paper, not the top line. Also, do not mark calibrations on the scale; merely obtain reference points of 0 signal (bottom line) and full-strength signal (center line).

NOTE: To calibrate the set-up used for high gain measurements, it may be necessary to remove the attenuation from the output circuit when bypassing the device under test for calibration purposes, to restore the signal to a level commensurate with that to be measured during the test. Before making test measurements, re-insert the attenuation in the output circuit.

c. Use the zero offset controls to move the "full-strength signal" trace from the center line to the bottom line of the CRT graticule or graph paper. This becomes the 0 db gain reference.

d. Calculate scale values to calibrate the graph paper or graticule, based on the relation of each scale deflection point to the known half-scale deflection offset which represents the incident signal level. Use the equation given in Step g of 3.17.6.2 above.

Example A

Calibrate the scale division points on a 6-cm scale:

Bottom Line: 0 db gain reference.

1st division: Power Level = 1-1/3 that of incident signal, since incident signal is calibrated for half-scale deflection before offset. 10 log 1.33 = 1.24 db.

2nd division: output = 1.66 x incident power
10 log 1.66 = 2.2 db.

3rd (center) division: 10 log 2 = 3 db

4th division: 10 log 2.33 = 3.67 db

5th division: 10 log 2.66 = 4.25 db

Top Line: 10 log 3 = 4.77 db

e. If the gain is more than 4.75 db, it will be necessary to decrease the vertical amplification of the oscilloscope sufficiently to bring the trace on-scale. In order to retain the scale calibration established above, this change of sensitivity must be made with only the stepped adjustment control, without changing the zero or calibration vernier adjustments previously set to calibrate the trace. The db value of any amplification decrease must be added to the gain read directly from the calibrated scale. If the output detector crystal is operating in its square-law range, the db value is 10 times the $\log_{10}$ of the amplification change ratio: 2:1 = 3 db; 5:1 = 7 db; 10:1 = 10 db; 20:1 = 13 db; 50:1 = 17 db; 100:1 = 20 db, etc.

NOTE: If the calibration was performed with the output detector connected directly to the primary output terminal of the input coupler, the db value of the output attenuator or coupler which was bypassed for calibration must be added to the gain read directly from the calibrated scale during performance measurements. If in this case the vertical amplification must be increased to obtain an on-scale test measurement presentation, the db value of this increase must be subtracted from the gain reading. Hence, the scale in this case is augmented by an amount equal to the output attenuator loss or coupler ratio, less any increase in vertical amplification in db.

f. Connect the device under test into the test circuit as shown in Figure 3-14. Without changing the zero or calibration vernier adjustments previously set to calibrate the trace, read the attenuation from the calibrated scale. If necessary switch to another vertical channel amplification step that brings the trace closest to full-scale deflection. Then interpret the db value of the scale reading as directed in Step e.

g. Obtain recorder plots or oscilloscope photos for permanent record as desired.

h. Repeat Steps f and g for all devices to be tested.

3.17.7 TECHNIQUE FOR VSWR MEASUREMENTS WITH DIRECT-READING METERS. A direct-reading VSWR meter may be connected to the reflected power detector output shown in Figure 3-11, replacing an oscilloscope or recorder. The proper location for connection of a direct-reading VSWR meter is also shown in Figure 3-12. A direct-reading ratio meter may be driven by using internal leveling in the Model 6400 and utilizing the incident power sampling coupler shown in Figures 3-11 and 3-12 to drive the reference channel of the ratio meter. Measurement techniques using these specialized meters are covered adequately in the instrument manuals for such meters. They may be used with either single-frequency operation or slow (100-second sweep) swept-frequency operation.

3.17.8 TECHNIQUE FOR POWER MEASUREMENT WITH DIRECT-READING METERS. A direct-reading power meter may be used by terminating the output circuit from the device under test at its power detector mount. The connection must be made through a suitable attenuator pad (or a coupler) to reduce the incident power level to that acceptable to the detector mount, which is usually 10 mw maximum. Measurement techniques are covered adequately in the instrument manuals for these meters. For greatest accuracy, single-frequency operation should be used. With some power meters, slow (100-second sweep) swept-frequency operation may be used.

3.17.9 IMPROVED MEASUREMENT TECHNIQUES USING THE UNIQUE ALFRED MODEL 8000/7051 NETWORK ANALYZER. This instrument provides dual-channel measurement capability for gain/loss ratios or absolute power levels, with direct db readout and a 60-db dynamic range. Full details are provided in Application Note 101 which is yours for the asking.

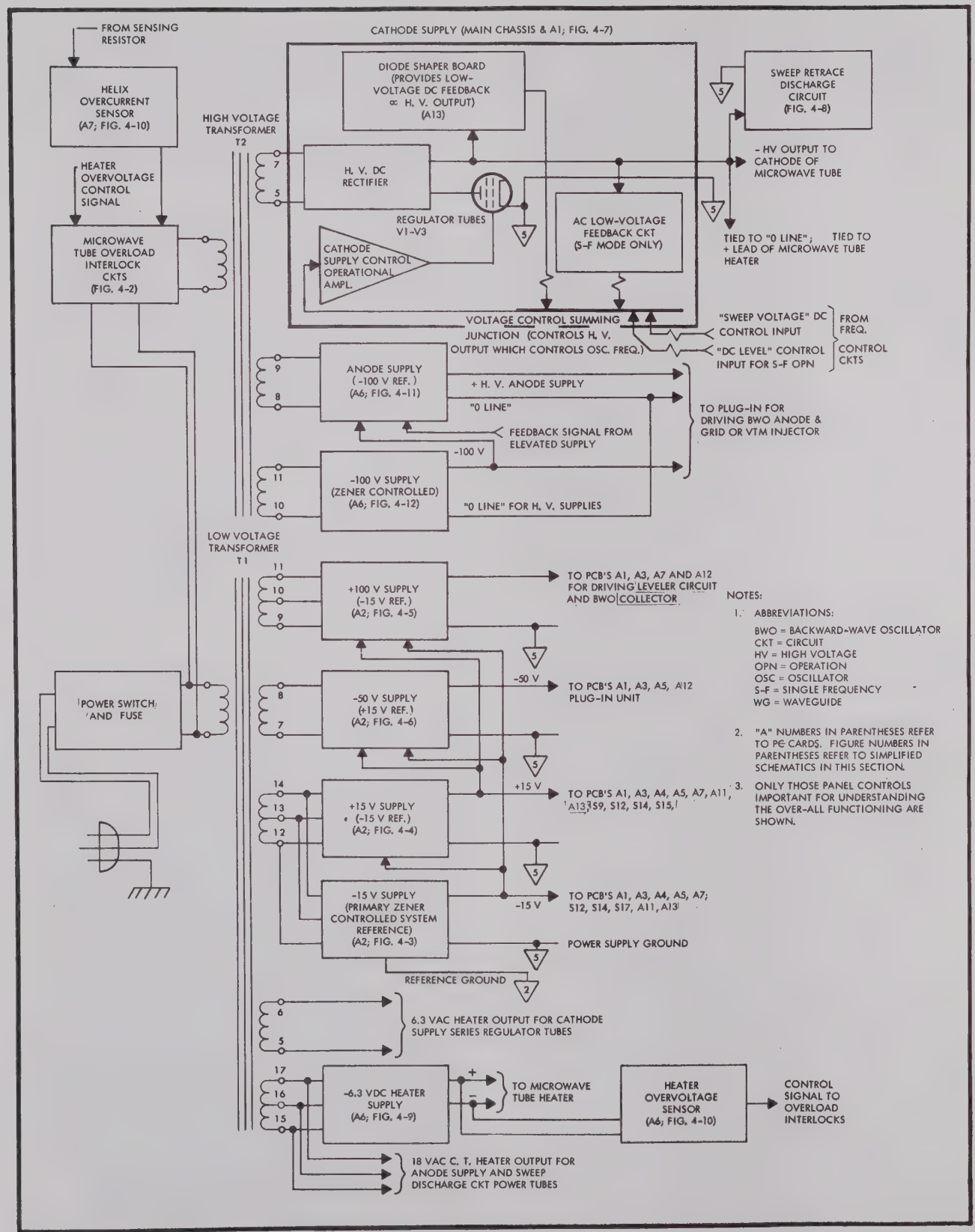

FROM SENSING RESISTOR
CATHODE SUPPLY (MAIN CHASSIS & A1; FIG. 4-7)
HELIX OVERCURRENT SENSOR (A7; FIG. 4-10)
DIODE SHAPER BOARD (PROVIDES LOW-VOLTAGE DC FEEDBACK ∝ H. V. OUTPUT) (A13)
SWEEP RETRACE DISCHARGE CIRCUIT (FIG. 4-8)
HIGH VOLTAGE TRANSFORMER T2
H. V. DC RECTIFIER
- HV OUTPUT TO CATHODE OF MICROWAVE TUBE
HEATER OVERVOLTAGE CONTROL SIGNAL
REGULATOR TUBES V1-V3
AC LOW-VOLTAGE FEEDBACK CKT (S-F MODE ONLY)
MICROWAVE TUBE OVERLOAD INTERLOCK CKTS (FIG. 4-2)
CATHODE SUPPLY CONTROL OPERATIONAL AMPL.
TIED TO "0 LINE"; TIED TO + LEAD OF MICROWAVE TUBE HEATER
VOLTAGE CONTROL SUMMING JUNCTION (CONTROLS H. V. OUTPUT WHICH CONTROLS OSC. FREQ.)
"SWEEP VOLTAGE" DC CONTROL INPUT
"DC LEVEL" CONTROL INPUT FOR S-F OPN
FROM FREQ. CONTROL CKTS
ANODE SUPPLY (-100 V REF.) (A6; FIG. 4-11)
+ H. V. ANODE SUPPLY
"0 LINE"
TO PLUG-IN FOR DRIVING BWO ANODE & GRID OR VTM INJECTOR
FEEDBACK SIGNAL FROM ELEVATED SUPPLY
-100 V
-100 V SUPPLY (ZENER CONTROLLED) (A6; FIG. 4-12)
"0 LINE" FOR H. V. SUPPLIES
LOW VOLTAGE TRANSFORMER T1
+100 V SUPPLY (-15 V REF.) (A2; FIG. 4-5)
TO PCB'S A1, A3, A7 AND A12 FOR DRIVING LEVELER CIRCUIT AND BWO COLLECTOR
POWER SWITCH AND FUSE
-50 V SUPPLY (+15 V REF.) (A2; FIG. 4-6)
-50 V
TO PCB'S A1, A3, A5, A12 PLUG-IN UNIT
+15 V SUPPLY (-15 V REF.) (A2; FIG. 4-4)
+15 V
TO PCB'S A1, A3, A4, A5, A7, A11, A13, S9, S12, S14, S15,
-15 V SUPPLY (PRIMARY ZENER CONTROLLED SYSTEM REFERENCE) (A2; FIG. 4-3)
-15 V
TO PCB'S A1, A3, A4, A5, A7; S12, S14, S17, A11, A13
POWER SUPPLY GROUND
REFERENCE GROUND
6.3 VAC HEATER OUTPUT FOR CATHODE SUPPLY SERIES REGULATOR TUBES
-6.3 VDC HEATER SUPPLY (A6; FIG. 4-9)
TO MICROWAVE TUBE HEATER
HEATER OVERVOLTAGE SENSOR (A6; FIG. 4-10)
CONTROL SIGNAL TO OVERLOAD INTERLOCKS
18 VAC C. T. HEATER OUTPUT FOR ANODE SUPPLY AND SWEEP DISCHARGE CKT POWER TUBES
NOTES:
1. ABBREVIATIONS:
BWO = BACKWARD-WAVE OSCILLATOR
CKT = CIRCUIT
HV = HIGH VOLTAGE
OPN = OPERATION
OSC = OSCILLATOR
S-F = SINGLE FREQUENCY
WG = WAVEGUIDE
2. "A" NUMBERS IN PARENTHESES REFER TO PC CARDS. FIGURE NUMBERS IN PARENTHESES REFER TO SIMPLIFIED SCHEMATICS IN THIS SECTION.
3. ONLY THOSE PANEL CONTROLS IMPORTANT FOR UNDERSTANDING THE OVER-ALL FUNCTIONING ARE SHOWN.

FIGURE 4-1. BLOCK DIAGRAM OF MODEL 6400 SERIES
(SHEET 1: POWER SUPPLY CIRCUITS)

SECTION 4

CIRCUIT DESCRIPTION

4.1 BLOCK DIAGRAM DESCRIPTION . (See Figure 4-1.)

4.1.1 GENERAL. A Model 6400 Series instrument consists of a chassis with 14 PC boards.

The PC boards and their functions are tabulated in Table 4-1 for reference in conjunction with the block diagram description and Figure 4-1.

4.1.2 POWER SUPPLY CIRCUITS. Sheet 1 of Figure 4-1 shows a functional block diagram of the power supply circuits in the Model 6400. Input power is applied directly to T1, and through an overload interlock to T2. This interlock removes high voltage power from the microwave tube if the heater voltage rises or if excessive current is collected by the helix of BWO tubes.

The low-voltage supplies are driven by T1. The -15 V supply, which contains a stable, temperature-compensated zener reference, is the primary voltage reference for the system. It is factory-adjusted to provide -15.0000 ± .0075 volts with respect to the common power supply ground, ⑤. A separate, "clean" reference ground, ②, serves as the return for the -15 V supply zener reference diode, and is connected to the ⑤ ground at only one point. The ② ground line is also used as a reference ground for the +15 V supply and certain frequency control and marker potentiometers. The -15 V supply serves as a reference for the +15 V supply and the +100 V supply. The +15 V supply serves as a reference for the -50 V supply.

The + and -15 V supplies are used for transistor bias and frequency control signal reference throughout the instrument. (The frequency control circuits are arranged so that a swing of 0 to +15 V shifts the output frequency across its full range.) The +100 V and -50 V supplies are used to drive biasing networks for cascaded amplifier stages. The +100 V supply provides screen bias for the high voltage regulator tubes in the cathode supply, and drives the collector bias circuit for the backward wave oscillator tube.

The 6.3 V dc heater supply drives the microwave tube heater. The regulator tube heaters are supplied with low-voltage ac; the V1, V2 and V3 heaters operate on 6.3 V from T1: 5-6, and the V4 and V5 heaters operate on 9 V from T1: 15-16 and T1: 16-17 respectively. The 6.3 V dc heater supply output is monitored by the heater overvoltage sensor.

The high-voltage supplies are driven by T2. The -100 V supply serves as a reference for the anode supply, and also drives the grid bias circuit in the elevated supply for the BWO tube. The anode supply output level is controlled by feedback from the elevated supply, and varies from +30 V to +280 V depending upon the BWO tube used. The anode supply output drives the anode bias circuit for the BWO tube. The return line of both the anode and -100 V supplies is denoted as the "0 line", and it is ground-referenced only through the cathode supply. The cathode supply negative high-voltage output is tied to the "0 line" thus placing the grid bias (-100 V supply) below cathode potential.

The cathode supply is a high voltage dc supply in which the output level is controlled by an operational amplifier which drives the series regulator tubes. The input signals to the operational amplifier consist of currents derived from low-voltage positive control signals from the frequency control circuits in the main chassis, and low-voltage negative dc feedback from the diode shaper board. These currents are summed at the operational amplifier summing junction.

All control and feedback signals are applied to the summing junction through 15 K. The frequency control circuits are arranged so that 0 V is applied across 15 K to the summing junction for frequency output at the low end of the band, and +15 V is applied across 15 K for frequency output at the high end of the band. The control voltage range is linear with frequency in between. Thus, a control signal varying linearly from 0 to 1 ma is supplied to the summing junction for full-range frequency control. The negative feedback through the diode shaper board supplies an opposing current to the summing junction that exactly cancels the control current when the cathode supply output voltage is correct to produce the selected output frequency for the tube in use.

Through proper arrangement of feedback, the cathode supply output can be controlled over a range as great as -150 V to -2500 V in response to control signals of between 0 and +15 V. For single-frequency operation, where a constant output voltage is required, negative ac feedback is applied to the summing junction through a low-voltage converting network to stabilize the output.

For swept operation, a low-voltage sweep is applied across 15 K to the summing junction, and the output is swept from a low negative voltage to a high negative voltage. To permit rapid discharge of the cathode supply output capacitance when the voltage must suddenly drop from a high to low negative value during sweep retrace, a self-triggering sweep discharge circuit is used to shunt the output capacitance.

4.1.3 FREQUENCY CONTROL, MODULATION AND RF OUTPUT CIRCUITS. Sheet 2 of Figure 4-1 shows a functional block diagram of these circuits. The sweep generator produces a control voltage ramp of 0 to 40 V with a slope established by the SWEEP TIME control. Successive sweeps are triggered automatically or by some other signal as selected by the SWEEP TRIGGER selector. The sweep generator also produces a ground-level retrace blanking signal during the sweep retrace and continuing through the "dead" interval before the next triggered sweep.

The sweep output circuit provides load buffering for the sweep generator. It supplies a 0 to +15 V ramp output to drive the $F_1 \rightarrow F_2$ sweep frequency control circuits and a zero-centered -0.75 to +0.75 V ramp output to drive the $F_0 \pm \Delta F$ sweep frequency control circuits.

The frequency control circuits include the five FREQUENCY and MARKER potentiometers (F_1, F_0, F_2, M_1, and M_2), the FREQUENCY Mode Selector switch S14, and the SINGLE Frequency Selector switch S15. These circuits produce the various swept and single-frequency modes as follows:

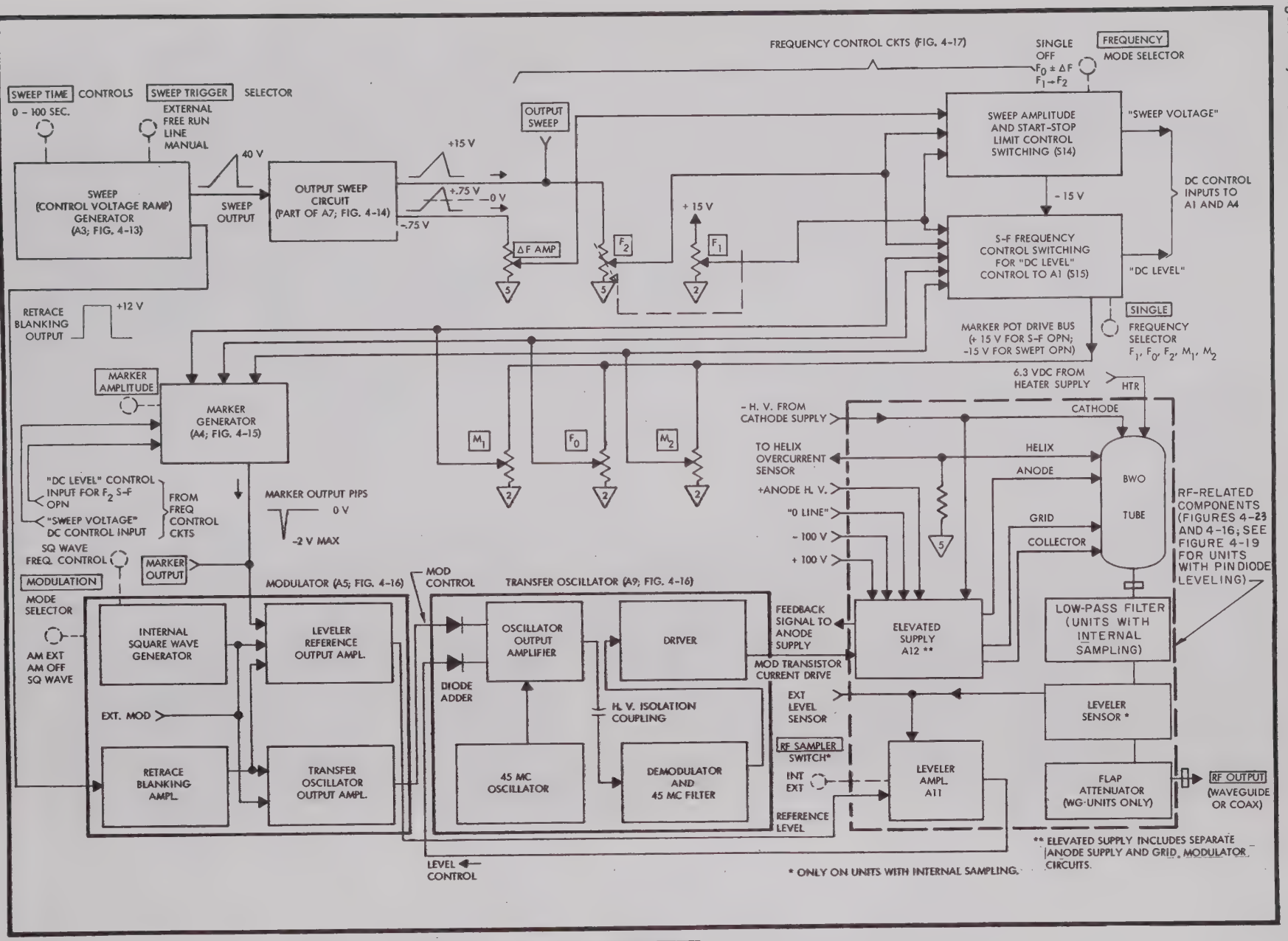


FIGURE 4-1. BLOCK DIAGRAM OF MODEL [redacted] 6400 SERIES
(SHEET 2: FREQUENCY CONTROL, MODULATION, AND RF OUTPUT CIRCUITS)

a. For $F_1 \rightarrow F_2$ swept frequency operation, the F_1 potentiometer output is connected to the "dc level" input to the cathode supply summing junction to provide a minimum-frequency starting point for the sweep. For connection to the "sweep voltage" dc control input of the cathode supply, a portion of the 0 to +15 V sweep ramp output corresponding to the frequency increment ($F_2 - F_1$) is obtained from the F_2 potentiometer. This is the voltage increment required to add to the F_1 potentiometer output to obtain a maximum control signal corresponding to F_2 at sweep end. This output from F_2 is obtained by a differential potentiometer drive arrangement where the F_2 knob controls the F_2 potentiometer wiper while the F_1 knob rotates the F_2 potentiometer body in the reverse direction, to subtract an amount equivalent to the F_1 setting from the F_2 wiper output.

b. For $F_0 \pm \Delta F$ swept operation, the F_0 potentiometer output is connected to the "dc level" summing junction input, and a reduced-level, zero-centered sweep from the ΔF potentiometer is applied to the "sweep voltage" dc control input.

c. For the OFF mode, the sweep generator is disabled and held at 0 V output. The resultant retrace blanking output signal is connected to the modulator to turn off the RF output.

d. For single-frequency modes, the output from the selected control potentiometer is applied to the "dc level" summing junction input, with no signal applied to the "sweep voltage" input. For this mode of operation, the marker control potentiometers M_1, F_0, M_2 are driven by +15 V supplied by S15, to provide the proper output polarity for frequency control. The F_2 potentiometer is driven by an adjustable voltage of 0 to +15 V supplied by the MANUAL SWEEP control (not shown). The differential control arrangement of the F_2 potentiometer is maintained in single-frequency mode, so that when the F_2 single frequency is selected, the F_1 potentiometer output is connected to the "dc level" summing junction input and the F_2 potentiometer output is connected to the "sweep voltage" summing junction input. The F_2 potentiometer output corresponds to $F_2 - F_1$ when the MANUAL SWEEP control is set to provide a full +15 V to the F_2 potentiometer. Thus, when the F_2 single frequency is selected the output may be manually swept from F_1 to F_2 by use of the MANUAL SWEEP control.

The marker generator is functional only during the swept output modes and the F_2 single-frequency mode (during which manual sweep may be used). It has a separate summing junction for each of the three markers. Each junction receives the same signals applied to the cathode supply summing junction during swept modes, but operates at a higher impedance level to allow isolation between the summing junctions. The three marker control potentiometers, M_1, M_2 and F_0, are driven by -15 V in the swept-frequency modes, supplied by S15. In the $F_0 \pm \Delta F$ swept mode, F_0 is not used as a marker, and receives +15 V to set the sweep center frequency. Each marker generator summing junction detects the null point when the positive frequency control voltages sweep across the negative level set on its marker potentiometer (corresponding to the rf output crossing of the marker frequency). The generator develops a negative-going marker pip signal with adjustable amplitude, which is connected to the output leveler circuit to produce an absorptive pip in the rf output level at each marker frequency during leveled operation. The marker output pulses are available at the front panel MARKER OUTPUT connector for use during unleveled operation.

The modulator circuit controls amplitude modulation of the rf output. It accepts external modulating signals and also generates a square wave signal for internal modulation. The retrace blanking signal from the sweep generator is applied to the modulator through switching circuits (not shown) to achieve output retrace blanking or rf off mode. All amplitude control signals processed by the modulator are split and applied to both the transfer oscillator (for control of the microwave tube) and the leveler-amplifier (to keep it from compensating for desired amplitude modulation). The one exception to this is the marker pulse train. To obtain optimum high-frequency response for narrow pips, the marker pulses are applied directly to the leveler.

The transfer oscillator couples the amplitude-modulation signals to the elevated supply. It provides high-voltage isolation between these low-level modulation signals and the tube supply circuits. The dc signals from the modulator and the leveler-amplifier are summed at the input to the transfer oscillator to permit amplitude modulation within a leveled envelope. When leveled operation is not used, the modulator signal alone drives the transfer oscillator. The input signals to the transfer oscillator control the amplitude of the 45-mc signal coupled from the 45-mc oscillator to the demodulator and filter. The high-voltage isolation is provided by capacitive coupling at the input to the demodulator. The driver converts the variable-level demodulator output signal into a current drive for a transistor modulator circuit in the elevated supply. This transistor circuit controls the voltage applied to the microwave tube modulating electrode.

The elevated supply PC Board A12 contains networks which combine and adjust the constant outputs of the anode supply and the +100 and -100 V supplies to provide the necessary anode, collector and grid drive for each BWO. It also contains a feedback network which sets the output level of the anode supply. Only one active stage is contained in A12, for control electrode bias. It varies the BWO grid voltage in accordance with the requirements of the tube for "full-on" to "rf off" in response to the output from the transfer oscillator. The diode shaper board A13 supplies the required dc feedback to the cathode supply to permit rf output frequency control with identical linear control signals, regardless of tube used. The leveler-amplifier A11 accepts rf level sensor signals from an internal or external sensor, compares them to a reference level, and drives the transfer oscillator or solid-state leveler to make any necessary output level corrections. The "reference level" signal to the leveler is modulated to prevent the leveler from correcting for desired modulation. The marker pulses are applied to the leveler via the "reference level" line to take advantage of the excellent leveler response for producing narrow marker pips.

4.2 PRIMARY POWER DISTRIBUTION. (See Figure 4-2.)

The power input through the line cord passes through the main fuse F2 on the rear of the chassis.

From S1, the power splits into two circuits to drive the low voltage transformer T1 and the high voltage transformer T2. The circuit to T1 is protected by fuse F1 located inside the chassis. The connection to the T1 primary windings is made through 115-230 VAC switch S3 located inside the rear of the chassis. S3 is arranged so that for 115 V operation, the two

Table 4-1 Printed Circuit Cards in the Model 6400 Series

PC Card Module Number	PC Card Name	Location on Chassis	Description
A1	Cathode Supply	Right Side (Fig. 5-2)	Contains the voltage control operational amplifier which drives the series regulator tubes in the high-voltage cathode supply and the buffer amplifiers which process low-voltage signals applied to the operational amplifier summing junction as a means of controlling the cathode supply voltage. This voltage, in turn, controls oscillator frequency. All high voltage circuit elements are on the main chassis, not on A1.
A2	Low-Voltage Supply	Right Side (Fig. 5-2)	Contains referencing and regulator amplifier circuits for the -15 V, +15V, -50 V, and +100 V supplies. The diode rectifiers and regulator transistors for these supplies are on A15 and the main chassis, respectively.
A3	Sweep	Right Side (Fig. 5-2)	Contains low-voltage sweep generator circuits used to drive the frequency control circuits to obtain sweep mode operation. Also contains trigger amplifier and control circuits for the various sweep triggering modes. Also generates the retrace blanking signal.
A4	Markers	Right Side (Fig. 5-2)	Contains circuits which detect when the output frequency sweeps through any preset marker frequency (by comparison of low-voltage control signals), and generates simultaneous marker modulating pulses.
A5	Modulator	Right Side (Fig. 5-2)	Contains a square wave generator and amplifier circuits which accept the internal square wave, markers, retrace blanking signals, or external modulation signals. It generates a control signal for the transfer oscillator and a reference signal for the leveler-amplifier A11.
A6	Auxiliary Supply	Inside Rear (Fig. 5-1)	Contains referencing and regulator amplifier circuits for the -100 V supply, the anode supply, and the microwave tube heater supply. Also includes the heater supply overvoltage sensor. The diode rectifiers and regulator transistors and tubes for these supplies are on A15, the main chassis, and A10, respectively.
A7	Helix Overcurrent	Right Side (Fig. 5-2)	Contains the helix overcurrent sensor circuit, and the completely independent output sweep circuit which provides buffering between the sweep generator and the frequency control circuits which use the sweep.
A9	Transfer Oscillator	Top Rear (Fig. 5-1)	Contains an rf oscillator which has its output amplitude controlled by signals from the modulator and leveler-amplifier. Includes an isolation transformer and an output rf-to-dc converter which drives the elevated supply A12 to control BWO rf output amplitude modulation.
A10	Series Regulator/ Retrace Discharge Assembly	Right Rear (Fig. 5-1)	Contains the regulator tubes for the cathode supply (V1 - V3) and the anode supply (V4); and the retrace discharge tube (V5) and associated circuits.
A11	Leveler-Amplifier	Behind Front Panel (Fig. 5-1)	Contains amplifier circuits which receive a reference level input from the modulator (A5) and signal-level inputs from an internal or external sensor. Develops an output signal which drives the transfer oscillator (A9) in grid-leveled units and the PIN diode leveler in diode-leveled units, to reduce the output level to a constant value across the band.
$A11_1$; $A11_2$	Leveler Interconnection Module	Behind Front Panel (Fig. 5-1)	Provides leveler interface between the standard chassis circuits and the particular leveler-amplifier and leveler connections used in each model. $A11_1$ is used for grid-leveled units, and $A11_2$ is used for PIN-leveled units. On units having $A11_2$, the PIN leveler power supply $A11_{ps}$ is installed at the right rear of the chassis (Fig. 5-3).
A12	Elevated Supply	Left Rear (Fig. 5-1)	Contains voltage-controlled networks which couple the high-voltage supply outputs to the appropriate electrodes of the microwave tube. Includes an active stage for modulating the BWO grid voltage in response to dc control signals from the transfer oscillator.
A13	Diode Shaper Board	Right Side (Fig. 5-2)	Contains a diode-resistor network which generates low-voltage feedback form the cathode supply output for application to the control operational amplifier of the supply. In BWO units, the feedback output is a non-linear function of supply output voltage, which compensates for the non-linear V/F characteristic of the tube to allow frequency control with linear signals. The PC card also contains a buffer amplifier for the feedback output signal.
A14	Protection/ Aux. Sig. Circuit	Top Center (Fig. 5-1)	Contains relay trip-out circuit for heater protection, pen-lift relay, and bias resistors for remote frequency and level control circuits.
A15	Rectifier Assembly	Top Center (Fig. 5-1)	Contains the diodes and packaged bridge rectifiers used in all low- and high-voltage supplies.
A19	Anode Protection	Right Side at rear (Fig. 5-1)	Used only for instruments having Varian-type BWO tubes. Protects against anode overload.
A25	High Voltage Feedback Resistor Board	Right Side (Fig. 5-2)	Provides low voltage feedback from cathode voltage by frequency control circuits. This board contains only 6 resistors (connected in series) with a capacitor connected across them.
A26	Bleeder Assembly	Top, left of center (Fig. 5-1)	Bleeds off high voltage stored in Cathode supply capacitors when instrument is turned off.

windings are connected in parallel; while for 230 V operation they are connected in series. Thus in either mode of operation, 115 V power is applied to each winding. The 115 V applied to one winding is used to drive the POWER ON light DS1. The low-voltage outputs from T1 are utilized to drive the low-voltage power supplies and tube heater circuits shown in Figure 4-1.

The primary power to high voltage transformer T2 passes through the protection circuit consisting of relays K1 and K2 and the top and rear panel interlock switches S5 and S6. This circuit is protected by fuse F3 located inside the chassis. The interlock switches are located just behind the removable top and rear cover panels (which permit access to high voltage circuits) so that these panels must be installed to close the switches.

The 60-second time delay relay K1 prevents application of high voltage power until the microwave tube has been warmed up by its heater and the low voltage supplies have had time to stabilize. When the instrument is initially turned on, high voltage relay K2 is de-energized, and its contacts B-1 connect terminal K1-6 to ground, completing the 6.3 V ac circuit through the heater of K1. After 60 seconds, the K1 contact closes, completing the ground return path of the K2 coil. K2 then energizes and completes the primary power circuit for T2 through its contacts A-2. The circuit includes contacts A-1 of protection relay K3, which is normally de-energized. If the protection circuits detect a heater overvoltage or helix overcurrent condition, relay K3 will be energized to remove primary power from T2, thereby disabling the high voltage supply. Operation of the protection circuits to supply +100 V to the K3 coil is described in Paragraphs 4.7 and 4.8. Once K3 has energized, it self-latches through its contacts B2 and the HV RESET button. When S4 is pressed, it allows K3 to de-energize if the overload condition has been corrected.

The connection to the T2 primary coils is made through 115-230 VAC switch S3. The 115 V applied to one winding is tapped to drive the H. V. ON light DS2.

4.3 +15 AND -15 VOLT POWER SUPPLIES. (See Figures 4-3 and 4-4.)

The +15 and -15 volt power supplies provide the low voltage outputs which are used for reference voltages and control circuit power throughout the instrument. The -15 V supply serves as the primary reference, and its primary reference standard is A2CR1, a 1N823A temperature-compensated zener diode.

The -15 V supply consists of a two-stage differential amplifier (dual transistor A2Q8, and A2Q6-A2Q7), a driver (A2Q5), and a series regulator transistor (Q4). The components shown within the dotted border in Figure 4-3 are located on L. V. Supply Circuit Board A2, accessible from the right side of the instrument. The use of metal film resistors in all critical circuits, and matched transistors in the input stage at A2Q8, minimizes noise and drift in this supply. As in all closed-loop feedback systems, tight control of phase response must be maintained. This is accomplished by A2C5 and A2R34 located at the differential amplifier output, the collector of A2Q6.

The feedback loop operates as follows to keep the output constant at -15 volts: If the output should tend to increase negatively to more than -15 V, the forward emitter-base bias on the right half of A2Q8 will increase more than that of the left half. This is because A2CR1 holds the base voltage constant on the right half, while voltage divider A2R17, A2R18, and A2R19 drops the base voltage applied to the left half when the -15 V output drops. The output of the first differential amplifier stage will then couple a more negative signal to the base of A2Q6 than to A2Q7 because of heavier conduction through A2R21. This will, in turn, increase the conduction through A2Q6 which tends to make the base of A2Q5 less negative. The conduction of A2Q5 is reduced, causing its emitter voltage - and therefore the base of the series regulator transistor - also to become less negative.

This action decreases the conduction of regulator transistor Q4 so that it offers greater series resistance in the output line, returning the level to exactly -15 V. If the output should tend to decrease to less than -15 V, the feedback loop will restore the output level by increasing the conduction of Q4. The -15 V output is connected to TP4 on the right side of the instrument. Potentiometer A2R18 permits precision adjustment of the -15 V output by establishing the proper quiescent operating bias for the first differential amplifier stage. Since the -15 V supply serves as primary reference for the instrument, it must be set to -15.0000 V ± 0.0075 V.

The -15 volt supply output is applied to A2R10 in the +15 V supply to serve as a reference for the +15 V supply. Except for the reference circuit, the +15 V supply circuitry is functionally identical to the -15 V supply. A2Q4 is the dual matched transistor first differential amplifier stage, A2Q2 and A2Q3 constitute the second differential amplifier stage, and Q3 is the series regulator transistor.

The components of the +15 V supply shown within the dotted border in Figure 4-4 are also contained on L. V. Supply circuit board A2. Potentiometer A2R9 in the reference string between the -15 V reference and the +15 V supply output provides for adjustment of the differential amplifier reference to obtain exactly +15 V output from the supply. The main phase response control is provided by A2C2 and A2R5 across the collectors of A2Q4. The +15 V output is connected to TP2.

4.4 +100 AND -50 VOLT POWER SUPPLIES. (See Figures 4-5 and 4-6.)

In addition to the +15 and -15 volt supplies there are two other low-voltage sources: the +100 and -50 V power supplies. The +100 V supply consists of a single stage differential amplifier, A2Q9 and A2Q10, which controls a driver stage, A9Q13, that drives the series regulator transistor Q1. A neon bulb, DS3, protects Q1 during turn-on. The +100 V supply uses the -15 V supply as a reference.

The -50 V supply consists of an amplifier (A2Q12), a driver (A2Q11), and a series regulator transistor (Q2). The +15 V supply serves as the reference for this supply. Phase response is controlled in the driver stage by means of A2C10 and A2R37. Diode A2CR2 provides temperature compensation and diode A2CR3 prevents transients from damaging A2Q12.

Components shown within the dotted border in Figures 4-5 and 4-6 are contained on the L. V. Supply circuit Board A2 along with the + and -15 volt supply components. The +100 V and -50 V supply outputs are brought out to TP1 and TP5, respectively, on the right side of the instrument.

4.5 CATHODE SUPPLY. (See Figure 4-7.)

4.5.1 GENERAL. The cathode supply provides adjustable high voltage to drive the cathode of the microwave tube and permit voltage-tuning of the rf output frequency. The supply contains a solid-state operational amplifier which drives the series regulator tubes. It provides an output voltage in the kilovolt range which is varied in accordance with low-voltage tuning control signals applied from the control circuits. The

control voltages are developed from constant-impedance sources and converted to currents by summing resistors that couple them to the amplifier input summing junction. There, they are summed with a dc feedback signal derived from the supply output to reduce the summing junction current to zero when the amplifier generates the correct high-level output voltage to operate the microwave tube at the desired frequency.

Because the tuning curve of a backward wave oscillator (BWO) tube is non-linear, the output of the cathode supply for BWO plug-in units must vary in a non-linear fashion with respect to the linear input control signals. This is necessary to achieve an output frequency directly proportional to the control signals which vary linearly with frequency.

To accomplish this variation in cathode supply output characteristics versus frequency for different plug-in units, the dc feedback signal from the supply output is derived in a Diode Shaper Board (A13). A different A13 board is used with each different tube. Other components of the cathode supply are standard and are contained in the chassis and the A1 PC board. In addition to providing output shaping for the cathode supply voltage, the Diode Shaper Board also provides adjustments for the absolute voltage level at each end of the tuning range, to allow setting the proper over-all slope and voltage calibration for the non-linear supply output, to meet the exact requirements of each tube.

4.5.2 OPERATIONAL AMPLIFIER AND SUMMING JUNCTION. The cathode supply operational amplifier consists of three differential stages and an emitter follower. A1Q1 is the input or first stage, A1Q2 and A1Q3 constitute the second stage, and A1Q4, A1Q5 and A1Q6 make up the third stage. The operational amplifier output stage is A1Q7, an emitter follower which drives the grids of the high voltage series regulator tubes V1, V2 and V3. These tubes are operated in parallel to control the output voltage of the supply. They are connected between the + side of the full-wave high voltage rectifier and ground, so that the voltage drop across the tubes reduces the effective high-voltage output level.

Resistors A1R8 and A1R12 are placed across the collectors of the first two differential stages to establish an amplifier gain independent of transistor parameters. The primary phase response of the amplifier is determined by A1C6 and A1R15 at the collector of A1Q6. A1CR1, at the base of A1Q7, is a 75-volt zener diode which changes the amplifier output dc voltage level at the collector of A1Q6 from about +50 volts to approximately -25 volts, to operate the grid driver emitter follower below power supply ground, as required by the grids of V1-V3.

All signal inputs to the operational amplifier are applied to the input summing junction as currents from high-impedance sources. The operational amplifier drives the cathode supply to maximum output voltage when the sum of the control signal input currents is 1 ma, in order to provide maximum negative feedback current to reduce the net summing junction current to zero. The control circuits are arranged to supply this maximum input when set for the signal output frequency at the high end of the band. The negative dc feedback current produced by the Diode Shaper board balances the control current when the output voltage reaches the required high-frequency voltage drive, as preset for the particular tube in use. The operational amplifier drives the cathode supply to its minimum output voltage when the sum of the control signal input currents to its input summing junction is 0. This output voltage corresponds to the low-frequency voltage drive point selected by an adjustment on the Diode Shaper Board, at which point the net feedback current it generates drops to zero. Thus, the net summing junction current is reduced to zero at that level of voltage output, and no further reduction in voltage takes place. The control circuits are arranged to supply zero input current when set for the frequency at the low end of the band. For all in-between frequencies, the control signal input varies linearly from 0 to 1 ma, and the diode shaper board provides feedback to exactly cancel the control signal when the proper high-voltage output level is reached.

There are four primary inputs to the summing junction: two control signals and two feedback signals. These are shown in heavy lines in Figure 4-7. Secondary balancing and external frequency control signals are shown in light lines. The two feedback signals are the dc feedback, which controls the output voltage level as described above, and an ac feedback to reduce ripple and noise on the supply when the oscillator tube is operating at a single frequency without modulation.

4.5.3 FEEDBACK SIGNALS TO SUMMING JUNCTION. The ac feedback circuit consists of C16, a 0.005 μf, 6000 volt capacitor located on the main chassis, and a two-stage current amplifier A1Q8 and A1Q9 on the Cathode Supply PC Board A1. Diodes A1CR2 and A1CR3 clip transients of either polarity to prevent overload damage to A1Q8. The ac feedback amplifier serves as an impedance converter, receiving its input as a voltage ripple on the high-impedance cathode supply output, and providing a low-impedance current drive signal to the summing junction. The amplifier output, from emitter follower A1Q9, is fed through the necessary front-panel switching to terminal W of PC Board A1 and then to the summing junction input of the operational amplifier. Switches S12A and S14M remove the ac feedback when the instrument is operating with a swept or modulated output signal. S12A and S14M connect the ac feedback to the summing junction only when the instrument is in the single-frequency operating mode with amplitude modulation off. This feedback drives the summing junction to correct any fluctuations in the steady-state output voltage.

The dc feedback, which controls the cathode supply output voltage, is derived from feedback resistors R81 through R85 on high voltage feedback board A25 and resistors A13R1 through A13R11 on the Diode Shaper Board A13. The voltage from this divider is applied to a two-stage current amplifier A13Q1 and A13Q2. The output of A13Q2 is fed through two temperature-compensating silicon diodes, A13CR13 and A13CR14, to terminal Z on PC Board A1 and then to the summing junction input of the operational amplifier. The shaper diode-resistor network consisting of A13-CR1 through A13CR10 and A13R3 through A13R11 provides the required non-linear feedback arrangement by forming a curve from ten straight-line segments.

This network operates as follows: Resistor A13R2 is connected across the feedback path, and is progressively shunted by resistors A13R3 through A13R11 as the feedback voltage level increases (negatively) to the point where each successive diode is brought into conduction. This occurs when the feedback voltage level at A13R2 drops below the anode bias level of each diode, as derived from the resistor string A13R15 - A13R24 connected across the + and -15 V supply lines. This progressive shunting away of feedback current produces an increase in the slope of the output voltage with a constant input control voltage slope, so that the output voltage will rise in a non-linear fashion with respect to the input voltage.

Resistor A13R1, the "Start Frequency Adjust" control, sets the minimum supply output voltage (corresponding to low-end-of-

band operation). It injects a fixed minimum positive input current into the feedback system to produce the supply output level that generates a cancelling negative feedback signal when the control signal input is 0. Resistor A13R28, the "End Frequency Adjust" control, is set to achieve the appropriate feedback level for the output voltage required at the high end of the band, when R2 is fully shunted by the shaper network.

The "Max Cal" control A1R38 on the cathode supply PC board provides an adjustment independent of the Diode Shaper board, to standardize amplifier and regulator gain with respect to the feedback loop.

4.5.4 CONTROL SIGNAL INPUTS TO SUMMING JUNCTION. The two primary control signal currents fed to the summing point are derived from the "dc level" input and the "sweep voltage." The "dc level" input is used for the sweep start-frequency voltage input and also for the single-frequency and symmetrical sweep center-frequency (F_0) voltage input. The signal applied to this input is determined by the front panel control switching.

For $F_1 \rightarrow F_2$ sweep operation, the positive sweep voltage input, a sawtooth with an amplitude proportional to the selected top frequency (F_2), is added to the start frequency voltage (proportional to F_1). For $F_0 \pm \Delta F$ sweep operation, a sawtooth centered on 0 volts with an overall amplitude proportional to $2\Delta F$ is added to the center frequency voltage proportional to F_0. Thus, the negative portion of the sawtooth sweeps the frequency below F_0 and the positive portion sweeps it above F_0.

The primary control signal inputs are impedance-converted to drive the summing junction through 15 K as constant-current sources. The impedance converter circuit utilizes a form of operational amplifier known as the voltage follower, in order to reduce the resultant loading on the panel control potentiometers in the dial assembly. The voltage followers consist of A1Q10 and A1Q12 on the "dc level" input, and A1Q11 and A1Q13 on the "sweep voltage" input. These amplifiers characteristically offer a very high input impedance while maintaining a very low output impedance for summing point drive. They do not invert the signal. Signal voltages for the marker circuits are also taken from the outputs of the voltage followers, to furnish frequency-related marker circuit drive without loading the panel control potentiometers.

There are two additional input signals fed to the summing point, the external fm input and the balance input. The balance input is set by "Balance" control A1R24, and is used to balance the emitter-to-base voltage of the input transistor pair A1Q1.

The external fm input permits control of output frequency with a remote low-voltage source. The dc input resistance of the external fm input is 15 K. Thus, 15 V will produce maximum signal input current of 1 ma and, therefore, the maximum frequency.

CAUTION: When using external frequency modulation, the external signal is added to the signals from the panel controls. Be careful to avoid a summing junction current in excess of 1 ma. For example, when the frequency is set to a mid-scale value (50 on the logging scale) using the panel F_0 control, the maximum dc or peak ac voltage at the FM INPUT jack must not exceed 7.5 volts. This will result in 0.5 ma through A1R5, which will add to the 0.5 ma through A1R3 from the mid-scale "dc level" input to produce 1 ma junction current.

4.5.5 OUTPUT CONNECTIONS. The "0 line" used as a reference point in other high voltage dc supplies and circuits is tied directly to the cathode supply output. With BWO tubes, the grid must be operated at a negative voltage with respect to the cathode. Since the "0 line" is the return line for the -100 V supply, the -100 V supply output, which is used for biasing the grid, is more negative than cathode potential.

4.5.6 SWEEP RETRACE DISCHARGE CIRCUIT. (See Figure 4-8.) The cathode supply output is capacitively loaded by C14 and other stray circuit capacitance. To permit rapid discharge of the supply output capacitance during sweep retrace when the output rapidly drops from the maximum to the minimum negative voltage, a sweep retrace discharge circuit (PC Board A10) is used. This circuit, shown in Figure 4-8, consists of high voltage beam pentode A10V5 and control transistor A10Q6 and A10Q7.

During retrace, the cathode supply output voltage tries to become less negative very rapidly, and the rate of change is limited by the rate at which C14 can be discharged into the load. Tube A10V5 is brought into conduction during retrace only, to quickly discharge C14 by completing a circuit through R52 and R56. The connection of the cathode supply, as shown in Figure 4-8, places C9B in the C14 discharge path through V5. Since C9B has about 400 times the capacity of C14, it is not significantly affected by the current flow required to discharge C14.

During the sweep, A10V5 is cut off by its low grid voltage, produced by the lack of current through A10Q7 which is biased to cutoff due to the strong conduction of A10Q6, which drops the junction of R55 and R57 to ≈ -100 V. A10Q6 is biased to strong conduction by the reverse leakage current through A10CR19. When retrace begins, the discharge current of A10C15, through A10R58, produces a large voltage drop which bucks out the voltage that was forcing a reverse current through A10CR19. This eliminates the positive base bias and cuts off A10Q6, thereby raising its collector voltage toward 0-line potential. The resultant increase in voltage across A10R57, which then acts as a voltage divider across 100 V with A10R55, brings A10Q7 into conduction, turning on A10V5. When retrace ends, the elimination of the A10C15 discharge current through A10R58 again allows A10Q6 to turn on, eliminating the bias across A10R57 and thereby cutting off A10Q7 and A10V5. A10R52 provides a convenient low-voltage monitoring point for the sweep discharge current.

4.6 HEATER SUPPLY. (See Figure 4-9.)

The heater supply for the microwave oscillator tube is a regulated dc supply using a series regulator transistor and a two-stage transistor amplifier. The heater supply control amplifier consists of A6Q6 and A6Q7, mounted on the A6 PC board, and series regulator transistor Q5 mounted in the main frame. The reference voltage is supplied as a fixed offset from the loaded output level by zener diode A6CR3. The A6Q7 emitter bias resistor A6R18 is returned to a constant -5.6V developed across A6CR10 by rectifier diodes CR21 and CR22. This provides the necessary biasing configuration for the direct-coupled amplifier stages A6Q6 and A6Q7. The amplifier input is provided by the difference between the output sample applied to the base of A6Q7 from A6R21, and the reference level (5.6 V below output level) developed at the emitter of A6Q7 by A6CR3. The heater voltage is set to 6.3 V at nominal line voltage, by adjusting A6R21 when 1 ampere of heater current is being supplied.

The heater supply output is connected directly to the BWO heater through connections in Elevated Supply PC Board A12. The

high voltage cathode supply is tied to the + output terminal of the heater supply within A12, so that the heater operates at a negative potential with respect to the cathode.

4.7 HEATER OVERVOLTAGE PROTECTION CIRCUIT. (See Figure 4-10.)

Transistor A6Q8, and its associated circuitry on Auxiliary Supply PC Board A6, in conjunction with Protection Circuit/Auxiliary Signal PC Board A14, form an overvoltage sensing and trip-out circuit. This circuit energizes relay A14K1 (Figure 4-10) to remove the voltage from the microwave tube heater if it rises to above 7 V. It also energizes relay K3 in the primary power distribution circuit (Figure 4-2) to turn off all high voltage power.

The positive output from the heater supply is applied to the tube through A14-7 and A14-22 by the contacts of relay A14-K1. The coil of this relay is energized by transistor A6Q8 which is normally non-conducting. In order for A6Q8 to conduct, the voltage drop across A6R22 must exceed 1.3 V. This is the voltage drop across the base-emitter junction of A6Q8 plus the voltage drop across A6CR5. Diode A6CR4 is a 5.6 V zener and is connected in series with A6R22 across the 6.3 V heater supply. Thus, it will be necessary for the heater voltage to go to 6.9 V before the voltage drop across A6R22 will be the necessary 1.3 V to cause conduction in A6Q8. If this condition exists, then A6Q8 will conduct and will energize relay A14K1 which disconnects the heater supply from the oscillator tube heater. The other fixed contact on relay A14K1 will then apply the full unregulated heater supply voltage to the light bulb in the light-sensitive resistor assembly A14DSR1. The light from this bulb illuminates the light-sensitive resistor and causes its resistance to drop to a very low value. This applies +100 V to the gate electrode of SCR A14Q9, triggering it to turn on and apply +100 V to the high voltage trip-out relay, K3 (Figure 4-2) which then energizes and removes all high voltages in the unit. To reset the instrument, the POWER switch must be turned off to unlatch the SCR, A14Q9.

4.8 HELIX OVERCURRENT PROTECTION CIRCUIT. (See Figure 4-10.)

The helix overcurrent circuit provides protection for the backward wave oscillator tube by operating relay K3 in the primary power distribution circuit to turn off all high voltages to the tube should the helix current rise above a preset maximum level. This level is given in the Addendum A sheet at the rear of this manual. This circuit consists of A7Q1, A7Q2, A7Q3, and A7K1 on the Helix Overcurrent PC Board, A7, which is mounted on the back of the front panel of the instrument. The circuit consists of a differential amplifier stage (A7Q2 and A7Q3) and a relay drive stage (A7Q1). The base of A7Q2 is connected directly to ground. The base of A7Q3 is connected to ground through A7R10, which shunts the helix current bleeder resistor A12R2 in the plug-in and therefore carries part of the helix current.

With no helix current flowing, the differential amplifier stage is balanced so that the relay control transistor A7Q1 draws sufficient current to keep relay A7K1 energized. The balance control for the differential amplifier is A7R5. If the current through A7R10 exceeds 1 milliampere, the increased conduction through A7Q3 robs current from A7Q2, and the resultant decreased conduction through A7Q2 causes the relay control transistor A7Q1 to reduce its current sufficiently to de-energize relay A7K1. This applies +100 V dc through the normally closed contacts of A7K1 to the high voltage interlock relay K3 in the main chassis (Figure 4-2). K3 then energizes, opening the circuit to the primary of the high voltage transformer and thereby removing all high voltages from the oscillator tube. K3 is self-latching and keeps the high voltage turned off until the RESET button on the front panel of the instrument is depressed.

4.9 ANODE SUPPLY. (See Figure 4-11.)

The anode supply provides power for the BWO tube anode. Each instrument incorporates appropriate resistor values in the anode voltage control feedback network to provide the correct voltage to the tube anode. The anode supply circuit consists of a full wave rectifier and regulator tube A10V4 which shunts the supply output resistors to provide output voltage control over a range from about 350 volts (tube cut off) down to about 25 volts (tube heavily conducting). The regulator tube is controlled by a regulator amplifier contained on part of Auxiliary Supply PC Board A6, and which consists of a differential input stage (A6Q10 - A6Q11) and output emitter follower driver stage A6Q9.

Since the BWO anode requires a voltage which is positive with respect to the cathode, the negative terminal of the anode supply is tied to the "0 line" which is referenced to the high-voltage cathode supply output line as shown in Figure 4-7.

The resistors which set the amount of feedback applied to the regulator amplifier, and thereby control the anode supply output voltage, are contained in the Elevated Supply PC Board (A12). A different feedback resistor A12R14 is used on the A12 board for each different tube. The -100 V supply is used as a reference for the voltage control network in A12 and also as the emitter bias return for the regulator amplifier in A6. Diodes A6CR7 and A6CR8, connected across the bases of the differential stage, are transient-protecting diodes which prevent damage to the input transistors in the event of malfunction. Diode A6CR6 provides bias for the emitter of A6Q9. Capacitor A6C5 with resistor A6R30 provides both ac feedback to reduce the ripple on the supply, and phase stabilization to prevent oscillations.

In BWO tubes, the anode is located in the gun structure to collimate the electron beam before it is accelerated to helix potential. The anode positive potential required may vary from 30 to 280 volts, depending upon tube type. The portion of Board A12 controlling the anode supply output voltage is shown in Figure 4-11. The voltage control network consists of "Anode Adjust" resistor A12R9 and A12R10 on the reference side and A12R11 and A12R14 on the feedback side. A12R9 is set to the point where the reference voltage supplied through it just balances the feedback voltage at the desired output level. The 50 K value of A12R9 is selected to provide high resolution. Since this low value (compared to A12R10) restricts the voltage adjustment range provided by A12R9, the feedback circuit is matched to the center adjustment point of A12R9 for the voltage required for each tube, by factory-selecting A12R14. To cover the full voltage range of the supply (30 to 280 volts), resistor A12R14 is selected from a table of values ranging from approximately 90 K ohms to 750 K ohms. This table is shown graphically in Figure 5-4.

For BWO tubes, the anode voltage does not change with modulation. Modulation is accomplished by controlling the grid (or by means of a separate PIN diode attenuator in the rf output line), both of which are independent of the anode supply voltage).

A diode-resistor network is used to improve the initial control response of the regulator amplifier when the instrument is turned on. At turn-on, little current flows through A6R25 so that the -100 V from the transistorized -100 V supply biases the

grid of V4 to prevent conduction. The forward drop across A6-CR7 is such that A6Q10 receives a stronger base drive from the voltage divider A6R26-A6R27, and it takes control of the differential stage, cutting off A6Q11. Until A6Q11 turns on, A6Q9 cannot be turned on to bring V4 into conduction to regulate the output voltage. As C8B is charged to the required level, the output across the bias string in the plug-in unit rises to the point where A6Q11 is biased to take control and turn on V4. Diode A12CR2 clamps the junction of A12R14 and A12R11 to the 0-line, to place a limit on the positive supply output excursion. This prevents the overshoot that would otherwise occur if less current were drawn from C8B through A12R14 during the turn-on delay time of V4.

4.10 -100 VOLT SUPPLY. (See figure 4-12.)

The -100 V supply furnishes power to the elevated supply in the plug-in for use in the grid control amplifier and for the anode supply feedback network. It also serves as a reference voltage for the anode supply and provides power to the transfer oscillator output stage. The -100 V supply uses a two-stage transistor differential amplifier (A6Q4-A6Q5 and A6Q2-A6Q3) to drive the series regulator transistor A6Q1. The reference voltage for this supply is derived from A6CR2, a 1N823 temperature-compensated zener diode. The zener voltage is compared to a portion of the -100 V output tapped from A6R5, in the input differential stage (A6Q4 and A6Q5). The output of this stage is applied to the second differential stage (A6Q2 and A6Q3).The output of the second differential stage is taken from the collector of A6Q2 and applied to the base of A6Q1, the series regulator transistor.

Neon bulb A6DS1 protects A6Q1 during the turn-on transient. Capacitor A6C3 and resistor A6R11, across the collectors of the input differential stage, provide the major phase correction for this amplifier. Capacitor A6C1, with resistor A6R8, provides ac feedback to reduce ripple and noise at the output of this supply. Diode A6CR1 connected to the base of A6Q4 provides a discharge current path for the feedback capacitor A6C1.

Since this supply is used as a reference for the anode supply, it is necessary that the voltage be set and regulated to 100.0 V ± 0.1 V. The positive terminal of this supply is tied to the "0 line," since the BWO grid must be biased negatively with respect to the cathode, and since the anode supply is also tied to the "0 line." The supply output is filtered by C9B.

4.11 SWEEP GENERATOR. (See Figure 4-13.)

The sweep generator consists of four major circuits contained on Sweep PC Board (A3):

a. The ramp generator - an operational integrator.

b. The retrigger multivibrator - a multivibrator circuit.

c. The retrigger delay - a modified Schmitt circuit.

d. The trigger generator circuit which includes the trigger hold-off amplifier.

The ramp generator includes transistors A3Q4, A3Q5, A3Q6 and A3Q7, connected in cascade to form a high-gain operational amplifier, and integrating (feedback) capacitors A7C1 through A7C4 selected individually by the SWEEP TIME switch S11. The input resistance is supplied by R31 and Sweep Time Vernier control potentiometer R30. The input stage is a silicon transistor A3Q4 operating at a collector current of approximately 10 microamperes. This will hold the input base current, obtained from the -15 V supply, to an absolute minimum. The second stage is an emitter follower, A3Q5, which minimizes the loading on the high collector impedance of the first stage. The third stage A3Q6 is a low-gain amplifier used for isolation of the high emitter impedance of the second stage. The fourth stage A3Q7 is a current amplifier whose collector load is R33, a 2.5 K ohm resistor connected to the +100 V supply. Resistor A3R44 reduces the power dissipation in A3Q7. The collector output signal of A3Q7 is fed back to the input of A3Q4 through one of the four feedback capacitors, selected for the desired integrating time constant. This output signal is a 40 volt ramp which is connected to terminal R. The ramp runs linearly from 0 to +40 V. When +40 V is reached, the retrigger multivibrator and retrigger delay process a pulse to reverse the current polarity at the operational amplifier input and quickly drive the sweep output back to zero. The 40 V sweep is connected to the trigger generator through A3R17, and to the retrigger multivibrator through A3R8 and diode A3CR2. A3R8 and A3R7 constitute a voltage divider which is connected to -15 V, to provide a zero crossover in the ramp output to the retrigger multivibrator. Diode A3CR2 is connected between the junction of A3R8 and A3R7 to convert the zero crossover into a pulse-type drive for the retrigger multivibrator.

The retrigger multivibrator consists of A3Q1 and A3Q2. When the voltage at the output of the ramp generator reaches approximately +41 V, A3CR2 conducts and a positive pulse is applied to the base of A3Q2. This causes the multivibrator to switch stages (A3Q2 conducting and A3Q1 non-conducting). The resultant positive voltage at the collector of A3Q1 is fed through resistor A3R37 and diode A3CR6 to charge capacitor A3C10. This positive voltage is also fed through emitter follower A3Q14 and then to the input of the "retrigger delay" Schmitt trigger (A3Q13 - A3Q12). A positive step function voltage appears at the collector of A3Q12 and is fed through A3R13 and A3C3 to the input of the ramp generator. This positive voltage swamps out the negative input through R30 and R31, and since the ramp generator now sees a positive rather than a negative input current, its output reverses direction and the sweep retrace begins. The retrace time is determined by the magnitude of the input current which, in turn, is determined by the value of A3R13 and the sweep retrace time resistors A7R11 and A7R12 which are connected in various shunt combinations by the SWEEP TIME switch S11. A3R13 is used alone in the .01 and .1 second sweep positions, shunted by A7R12 in the 1 second position, and shunted by A7R11 in the 10 second sweep position. The values of A3R13, A7R11 and A7R12 are selected so that the retrace time in the 10 milliseconds sweep position is approximately 2 milliseconds; in the 100 millisecond sweep position, approximately 20 milliseconds; in the 1 second sweep position, approximately 80 milliseconds; and in the 10 second sweep position, approximately 800 milliseconds. When the output voltage from the sweep generator reaches zero volts, diode A3CR7, connected between the input and output of the operational integrator, will conduct. This conduction effectively ties the input and output of the amplifier together and stops any further voltage decrease at the output terminal.

The output remains at 0 volts during a delay interval and until the next sweep ramp is triggered. The method of triggering differs with the setting of the SWEEP TRIGGER selector switch S10. In the FREE RUN sweep position, the 40 V sweep is fed through A7R15 back to diode A3CR1 and to the input of the retrigger multivibrator. This will reset the retrigger multivibrator by applying a negative pulse to the base of A3Q2 when the 40 V sweep is retraced to 0 volts (leaving A3Q2 non-conducting and A3Q1 conducting), and the voltage at the collector of A3Q1 will drop to a very low value. Since capacitor A3C10 is now positively charged, diode A3CR6 will be reverse biased and will not conduct.

This will allow capacitor A3C10 to discharge through A3R40, a 220,000 ohm resistor. After approximately 2 milliseconds A3C10 will have discharged sufficiently to cut off A3Q14, resetting the retrigger delay multivibrator and dropping the collector of transistor A3Q12 to a low voltage value. At this time the coupling diode A3CR3 will be reverse biased, isolating the operational integrator from the retrigger delay multivibrator. The operational integrator will again receive a negative input current from resistors R30 and R31, initiating the next sweep.

During the sweep, when the base of A3Q14 is biased to cutoff, A3Q15 is also biased to cutoff, so that the +100V supply is connected to the SWEEP light through A3R48. When retrace is initiated by application of a positive voltage to the base of A3Q14, A3Q15 is biased for heavy conduction and the resulting current flow through R47 drops the voltage applied to the SWEEP light, thereby extinguishing it. The light remains off until the base of A3Q14 is biased to cutoff at the start of the next sweep.

If the SWEEP TRIGGER switch S10 is in the EXTERNAL,LINE, or MANUAL positions, diode A3CR1 is connected to the junction of A3R22 and A3R32. This places ≈+3 V on the cathode of A3CR1, to reverse-bias it. In these modes, the reset pulse for the retrigger multivibrator is derived from the Schmitt trigger circuit, which consists of A3Q11 and A3Q10 driven from A3Q9. If the FREQUENCY mode selector switch S14 is in either sweep position, the base of A3Q16 will be + biased through A3R49 to saturate and provide a ground connection for the A3Q8/A3Q9 emitters. In the MANUAL position of the SWEEP TRIGGER switch, pressing the MANUAL TRIGGER button S9 applies +15 V through resistor A3R19 to the base of A3Q9. This causes A3Q9 to conduct heavily and its collector voltage will fall to a few tenths of a volt. This voltage, coupled to the base of A3Q10, causes the Schmitt circuit to reverse stages, with A3Q10 conducting and A3Q11 cut off. The resultant negative step function at the collector of A3Q11 will be differentiated by A3C8/A3R32, and the negative pulse is applied through A3CR1 to reset the retrigger multivibrator. Subsequent operation of the circuit is the same as in the FREE RUN mode.

If the SWEEP TRIGGER selector switch is placed in the LINE position, the input to the trigger generator circuit A3Q9 is derived from the power transformer T1. The biasing of A3Q9 is such that a negative trigger pulse will be generated each time the input waveform crosses zero in a positive direction. Since it is not desired to get a trigger pulse until the retrace is complete, it is necessary to de-activate the trigger circuit until that time. This is done by means of the trigger hold-off amplifier A3Q8. The base of this amplifier is connected through A3R17 to the 40 V sweep. Thus, as long as the sweep is positive, transistor A3Q8 will conduct. This conduction holds the collector voltage of A3Q9 at very close to zero volts. It then becomes impossible for trigger voltages to appear at the collector of A3Q9 and thus at the base of A3Q10. As soon as the 40 V sweep goes to zero during the retrace, A3Q8 will stop conducting. Its collector will go positive, resetting the Schmitt trigger by cutting off A3Q10 and turning on A3Q11. (The resultant positive output spike is isolated from A3Q2 by A3CR1.) The trigger generator circuit will then be ready to accept a trigger.

Once the next sweep ramp is triggered, further negative pulses from the Schmitt trigger will not affect the retrigger multivibrator. By the time the sweep output again resets the retrigger multivibrator, the Schmitt trigger is inhibited by the positive sweep voltage as described above until retrace is completed.

A ground connection is applied to terminal W of A3 when the FREQUENCY Mode Selector switch S14 is in the SINGLE frequency or OFF modes. This keeps transistor A3Q16 cut off, so that A3Q8 and A3Q9 cannot conduct. Thus, no sweeps can be triggered during these modes, and the ramp generator therefore rests at zero volts. In the EXTERNAL trigger position, positive trigger pulses can be introduced to A3Q9 by way of a front panel BNC connector.

When the retrigger multivibrator is switched to the A3Q2 conducting state to start the retrace period, the negative step-function collector output of A3Q2 is applied through A3CR8 to the panel RETRACE and FREQUENCY Mode Selector switches. In the RETRACE OFF condition this ground-level signal is connected to the modulator circuitry on PC Board A5, to turn the rf output off during retrace and until the next sweep is triggered. In the FREQUENCY OFF position of S14, it drives the modulator to keep the rf output off. This near-zero level is also applied by way of voltage divider A3R9 and A3R10 to the base of A3Q3. A3Q3 will then be cut off during retrace only, so that its collector will be at approximately zero volts during the forward sweep and approximately +50 volts during the retrace and until the triggering of the subsequent sweep. This 50 V blanking pulse has approximately a 10 K source impedance, and is connected to the BLANKING OUTPUT connector on the front panel.

4.12 SWEEP OUTPUT CIRCUIT. (See Figure 4-14.)

The sweep output circuit shown in Figure 4-14 is used to generate the sweep drive signal for the panel frequency controls. The output of these controls drives the summing junction in the cathode supply operational amplifier, and provides a sweep-level output to the marker circuits for use in determining coincidence between the sweep and the preset marker frequencies. The sweep output circuit also provides the 0 to +15 V monitoring signal for the front panel SWEEP OUTPUT connector. The active circuitry is contained on part of Helix Overcurrent PC Board A7.

The input signal to the sweep output circuit is the 40 V sweep ramp output from the sweep generator circuit in A3. It is fed through a voltage divider consisting of A7R2, A7R3, A4CR1 and A7R4 to the base of A7Q5. A7Q5 is an emitter follower which provides a high-impedance input to avoid loading the ramp generator, and furnishes sufficient output drive for both the marker and sweep control circuits. The "Sweep Amplitude" chassis adjust control A7R3 adjusts the gain of A7Q5 to provide an output sweep level of exactly +15 V maximum. The 0 to +15 V sweep output, at pin Z of A7, is distributed to the front panel switching controls.

When FREQUENCY Mode Selector switch S14 is in the $F_1 \rightarrow F_2$ swept mode position, S14E-4 connects the 0 to +15 V sweep to drive the F_2 control potentiometer R38. The wiper of R38 then taps off a reduced portion of the sweep sawtooth voltage corresponding to the setting of F_2 on the dial. This voltage is connected to the "sweep voltage input" terminal A1-U of the cathode supply. After impedance conversion in A1, it is coupled to the summing junction to provide swept drive from the starting frequency (set by the separate F_1 dc level input) to the F_2 frequency. The wiper position on the F_2 potentiometer R38 is such that it taps off sufficient voltage to sweep up to frequency F_2 from the low-frequency end of the band without considering the additional input to the cathode supply summing junction from the F_1 potentiometer (which will be zero only when F_1 is set at the low-frequency end of the band). Thus, a provision must be made to reduce the F_2 output voltage tap-

ped from R38 when F_1 is set above the low end of the band; otherwise the top frequency would be $F_1 + F_2$. The necessary correction is to adjust the F_2 output from R38 to equal a voltage corresponding to the frequency increment ($F_2 - F_1$) at sweep sawtooth maximum. This is done by a mechanical differential gearing arrangement in the dial drive mechanism. All the dial control knobs incorporate a 1:2 overdrive gearing arrangement to provide maximum potentiometer sensitivity with a minimum of dial rotation. The gearing of the F_1 and F_2 controls is arranged so that the F_1 control, in addition to operating the wiper of F_1 potentiometer R41, also rotates the body of F_2 potentiometer R38 around its wiper to reduce the R38 output voltage by an amount equal to the R41 output. This brings the R38 output to the necessary ($F_2 - F_1$) maximum value. The wiring connections to R38 are made by means of a coiled cord to permit this rotation without sacrificing wiring reliability.

When FREQUENCY Mode Selector switch S14 is in the $F_0 \pm \Delta F$ position, A14E-3 connects the 0 to +15 V output from A7-Z to an attenuating and dc offset network consisting of A7R7 and A7R6. This network offsets the signal output midpoint level applied to terminal A7-C to exactly zero volts, and reduces the sweep amplitude by 10:1, so that the sweep sawtooth applied to A7-C runs from -0.75 to +0.75 V. A portion of this zero-centered, reduced-amplitude sweep signal is tapped by the ΔF control potentiometer R42 and applied to the "sweep voltage input" terminal A1-U of the cathode supply. In this mode, the output of F_0 control potentiometer R44 is connected to the "dc level input" terminal A1-R of the cathode supply. The zero-centered sweep thus adds to the fixed F_0 level at the cathode supply summing junction, to sweep the output frequency symmetrically around F_0 by an amount corresponding to the ΔF setting.

When the FREQUENCY Mode Selector switch S14 is in the $F_1 \rightarrow F_2$ or $F_0 \pm \Delta F$ positions, the 0 to +15 V sweep output from A7Q5 is coupled through pin K of A7 to the base of A7Q4, the emitter follower driver for the SWEEP OUTPUT connector J11. The 0 to +15 V output from A7Q4 is fed through 10 K resistor A7R5, which serves as a source impedance for the external using circuit. The CALIB button S7 connects J11 through another 10 K resistor, R32, which is tied to the +15 V supply to furnish a +15 V calibration output.

4.13 MARKER GENERATOR CIRCUIT. (See Figure 4-15.)

The purpose of the marker circuit is to provide wavemeter-like pips to indicate preset frequencies selected with the F_0, M_1, or M_2 Control Knobs. One marker pip is electronically generated when the rf output crosses each selected marker frequency. The markers are generated by determining the time of coincidence between the absolute level of the 0 to +15 V sweep output signal and the preset marker generator signal level between 0 and -15 V, which corresponds to the position of each marker frequency in the swept spectrum. At each instant of coincidence, a modulation pulse is applied to the leveling circuit to momentarily reduce the output level. Each instant of coincidence is determined by a separate summing junction and operational amplifier for each of the three markers contained in Markers PC Board A4.

A description of the control signals which drive the cathode supply summing junction to control the frequency of oscillation of the oscillator tube is given in Paragraph 4.5. These same control signals are also used to drive the marker generator summing junctions, as a linear representation of instantaneous output frequency. These two control signal voltages are the "dc level" (start frequency) and "sweep" control signals which are tapped from the appropriate panel potentiometers by the front panel FREQUENCY Mode and SINGLE Frequency Selector switches S14 and S15. They are applied to terminals U and R of A1, as shown in Figures 4-7 and 4-17, and are impedance-converted on the A1 board. In addition to driving the cathode supply operational amplifier summing junction through 15 K, the control signal outputs from the two impedance converters are supplied to terminals S and P of A1. These outputs are used to drive the marker circuit summing junctions as shown in Figure 4-15.

The impedance converter outputs used in the marker circuits are connected to each summing junction through 100 K resistors. These resistors prevent any loading effect on the cathode supply impedance converters. To balance the source impedance of all inputs to the marker circuit summing junctions, the output signal from each marker control is also applied through a 100 K resistor. The signals applied to the cathode supply summing junction are then isolated from all inputs to any marker circuit summing junction by an effective impedance of about 200 K. This provides effective isolation, when compared with the low-impedance drive of the desired signals supplied from the impedance converters.

Only one marker circuit summing junction is shown in Figure 4-15. The signals from A1-P and A1-S are applied to all three circuits. The other two circuits are identical to the M1 circuit shown, except for the top input signal from the marker control potentiometer. (Different reference designators are also assigned to the other circuits, since they are all contained on PC Board A4; the complete A4 schematic is provided at the back of the manual.) The M_1 channel will be described as an example. The voltage input from MARKER control M_1, tapped from linear potentiometer R48, varies from 0 to -15 V linearly, depending upon the setting of M_1 on the frequency scale. The sum of the control voltages applied to A1-P and A1-S varies with instantaneous frequency through the same linear range, but with opposite polarity (0 to +15 V). Thus, the M_1 marker circuit summing junction will pass through a 0-volt null when the output frequency crosses the selected marker frequency. The marker generator, consisting of A4Q7 through A4Q12, indicates this momentary null condition by producing an output voltage change.

In the M_1 channel the marker generator consists of three cascaded amplifier stages (A4Q7, A4Q8 and A4Q9), a double-ended phase inverter stage (A4Q10 and A4Q11), a positive pulse-summing full-wave rectifier (A4CR7 and A4CR8), and an output emitter follower (A4Q12). Due to the very high gain of the amplifier, a very small variation in the input voltage above or below zero volts will drive its output from positive to negative saturation. Diode A4CR6 biases transistor A4Q7 to cut off when the summing junction potential is below 0 (it rests at about -0.5 V at the start of each sweep due to the negative signal from the marker potentiometer). The two following stages will conduct heavily when A4Q7 is cut off, thereby raising the base of A4Q10 to +15 V and keeping it cut off so that A4Q11 conducts heavily. Thus, if the frequency is swept very slowly up to the marker position, the voltage at the collector of A4Q10 will start out negative and suddenly jump to a positive value as A4Q7 starts to conduct and thereby turns on A4Q10. The voltage at the collector of A4Q11 will start out positive and suddenly jump to a negative value, as the turn-on of A4Q10 drops the emitter of A4Q11 below the cutoff point for its fixed base bias.

The two step functions of opposite polarity supplied from the collectors of phase inverters A4Q10 and A4Q11 are applied to rectifier diodes A4CR7 and A4CR8. These diodes are connected

to the base of A4Q12. The input waveform at A4Q12 is therefore a narrow, negative triangular pulse with about half the amplitude of the step function pulses. The leading edge of the triangular pulse is formed by the fall of the negative-going step function, and the trailing edge is formed by the rise of the positive-going step function. The tip of the output triangular waveform of A4Q12 thus represents zero volts at the summing junction. The collector of A4Q11 is connected through a resistive network back to the input of the amplifier for negative feedback stabilization.

The output of A4Q12, the triangular marker pulse, is combined with the markers from the other two marker channels and applied through resistor A4R74 to the base of A4Q19, another emitter follower. The output of A4Q19 feeds the marker pulses either to the front panel MARKER OUTPUT connector, (only in the switched EXT position of the MARKER AMPLITUDE control) or to the modulator PC Board A5, where the pulses are used to alter the voltage applied to the leveler amplifier to produce a pip in the power output. The marker output line is normally at ground level, and the pulse amplitude ranges up to -2 V. From the leveler-amplifier the markers are applied to the PIN-diode leveler or to the tube grid via the transfer oscillator and elevated supply. They modulate the rf output with absorptive marker pips, in leveled operation. For unleveled operation, the video pips available at the OUTPUT MARKER connector can be combined at the oscilloscope or recorder input with the detector output from the rf circuit, to provide markers in the display.

Marker amplitude is controlled by bleeding off a variable portion of the marker pulse drive current from the base of A4Q19 by means of MARKER AMPLITUDE potentiometer R37, which adjusts the return level of A4R73. With R37 at the OFF limit of rotation, A4R73 is returned to +15 V, and all drive current is shunted away from A4Q19. As R37 is turned CW, lowering the return voltage of A4R73, it becomes a less attractive shunt path for the marker pulse drive current, so that A4Q19 is driven to provide a variable marker pulse amplitude up to a maximum of -2 V. Diode A4CR13 prevents the base voltage of A4Q19 from being shifted above +0.6 V by the adjustment of R37.

During retrace in swept modes, the positive blanking voltage is supplied through A4R77 to inhibit the markers by shunting away all drive current. This blanking signal is removed from A4-T in the manual sweep mode by S14-O, to allow markers during manual sweep. (The M_1 and M_2 MARKERS potentiometers are disconnected from the marker generator circuit in all single-frequency modes except F_2, to inhibit markers except in the mode where manual sweep may be used.) "M_1 Cal" resistor A4R32 and summing resistor A4R31 inject a fixed offset current into the summing junction to permit marker dial calibration coinciding with the calibration of the frequency control dials. This compensates for tolerance variations in the components. Diode A4CR6 supplies a bias of -0.6 V to the emitter of A4Q7, so that its base, which will be at +0.6 V with respect to its emitter due to V_{BE}, will be biased at zero volts. If this were not done, the amplifier would become active, that is, unsaturated, when the summing junction voltage is +0.6 V rather than zero volts, placing a fixed offset error in the system. Another function of A4CR6 is to provide temperature compensation at the input of the marker circuit. Diode A4CR5 clamps the summing junction to ground to prevent unnecessary rises above 0 V after the trigger pulse has been generated.

4.14 MODULATOR. (See Figure 4-16.)

The amplitude modulation circuitry combines several modulating signals, sums them, and applies them to the transfer oscillator and from there to the elevated supply in the form of biasing voltage variations. Connections on the elevated supply and circuit the type of leveler board used in the instrument provide final determination of the applied voltage levels and connection configuration for the BWO tube.

The amplitude modulator circuitry is contained on Modulator PC Board A5. The signals used in the modulator for driving the plug-in include:

a. The internally-generated square wave (produced by stages A5Q1 through A5Q4).

b. The blanking impulse used to turn off the rf power during sweep retrace and when the FREQUENCY Mode Selector is OFF (applied to A5Q8 from the sweep circuit).

c. The marker pulses (applied to A5Q7 from the marker circuit).

d. External amplitude modulating signals (coupled through the plug-in unit to A5Q3).

e. The rf turn-on and turn-off voltages received from the MODULATION Mode Selector switch S12, the RETRACE Selector switch S12, the RETRACE Selector switch S13, and the FREQUENCY Mode Selector switch S14 (applied through A5-X and A5-T).

The modulator output, at A5Q5, is coupled to the elevated supply through the transfer oscillator, which raises the signal level to the elevated potential at which the tube operates. The transfer oscillator also combines another modulating signal - the leveler-amplifier output - with the modulator output signal to obtain the over-all power amplitude control signal for the microwave tube, in grid-leveled instruments.

In the internal square wave generator circuit, unijunction transistor A5Q1 serves as the oscillator, and operates at twice the square-wave frequency. The output pulses from A5Q1 are differentiated by A5C2 and A5R6, and applied to A5Q2. There, the positive pulses are amplified, reversed in polarity, and applied to a bistable multivibrator circuit containing A5Q3 and A5Q4. This circuit switches states and produces a 1 V output voltage swing that constitutes half a square wave cycle in response to each input pulse, thereby dividing the 2 kc pulse frequency by two, producing a 1 kc, 1 V peak-to-peak square wave: The output of this square wave multivibrator is obtained across A5R11 and applied to A5Q5 and A5Q6.

The signal from the collector of A5Q5 drives the transfer oscillator for modulation coupling to the plug-in. The signal from A5Q6 supplies the reference voltage for the leveler circuitry, so that it will not correct for desired modulation. The open-circuit output voltage from A5Q5 will be either 0 or +15 V corresponding to the +1 V and 0 V half cycles, respectively, of the driving square wave. Similarly, the voltage at the collector of A5Q6 will be either 0 or +7.5 V. (The collector of A5Q5 is returned to +15 V, while the collector of A5Q6 is returned to a voltage divider between +15 V and -15 V.) Due to the same voltage divider, the corresponding open-circuit output voltage from A5Q6 at terminal R, which feeds the reference voltage to the leveler, will be either -5 V or 0.

The voltage output at terminal R will be modified by the marker injection signal amplified by A5Q7, the collector of which is connected to the junction of A5R26 and A5R27. The negative marker pulses applied at A5-P cause A5Q7 to conduct, raising the voltage at this junction from -10 V to a less-negative voltage ranging up to -4 V, depending upon the amplitude of the marker supplied from the marker circuit. Thus, the

-5 V or 0 V output at terminal R will be raised to -2 or +1.75 V, respectively, during application of a maximum-amplitude marker. Since -5 V is required at A5-R to obtain the full-on (CW or swept) rf output level, the resultant -2 V signal will produce an amplitude reduction "pip" in the output level which serves as a marker. The nominal 0 to +15 V square wave level applied to the transfer oscillator through A5F is reduced to almost +11 V peak by output loading. This signal operates so as not to interfere with the rf output level during the 0 V portions of the output signal, and to reduce the rf output level when the square wave goes positive. Note that there is a phase reversal between the output of A5Q3 and the modulation signal applied to A5-F and A5-R.

Except for the markers, all other on-off control signals supplied to the modulator are applied at the base of A5Q3, the output stage of the square wave multivibrator. For operation without amplitude modulation, the MODULATION Mode Selector switch S12 applies +15 V to the base of A5Q3, to hold it in conduction. This is the condition corresponding to the +1 V portion of the A5Q3 output wave, as required to supply a 0 V signal to the modulator to allow the rf to remain on.

In the EXTERNAL MOD position of the Mode Selector switch, the positive A5Q3 bias is overcome by applying -15 V to terminal X and through A5CR4 and A5R22 to the base of A5Q3. A5R21 and A5R22 then constitute a voltage divider which places a negative bias on the base of A5Q3. This will hold A5Q3 cut off, and its output level will be zero, causing the rf to be turned off. In this condition, no rf output is supplied until positive voltage is applied to the EXT AM INPUT connector on the plug-in front panel. This voltage is connected to terminal A5-V, and through A5R20 and A5CR5 to the base of A5Q3. A sufficient positive input voltage (approximately +10 V) at the base of A5Q3 will buck out the negative bias and cause the multivibrator to change states, turning on the microwave oscillator tube. In the SQUARE WAVE position of Mode Selector switch S12, the +15 V supply is connected to the collector dropping resistors of A5Q1 and A5Q2, allowing them to operate to produce the internal square wave. This +15 V is removed in other modulation modes when the internal square wave is not required.

During swept operation, the retrace blanking pulse supplied at terminal W passes through the network A5R28, A5C6, and A5R29, and then is applied to A5Q8, an emitter follower. The signal as applied to A5-W is about 0 V during retrace and about +15 V during each sweep. The connection of A5R29 to -50 V adjusts the blanking pulse level applied to the base of A5Q8 to -6 V during retrace and +2 V during the sweep. The result is that A5Q8 conducts heavily during the sweep and lightly during retrace, providing an emitter output level of +1.5 V and -7 V, respectively. The signal from the emitter of A5Q8 is coupled out through A5CR3 and A5CR4. The -7 V signal coupled through A5CR3 during retrace turns off amplifier A5Q2. This prevents pulses from the unijunction transistor from driving the multivibrator. The -7 V signal coupled through A5CR4 is applied to the base of multivibrator output transistor A5Q3, holding that stage cut off during retrace, the condition required to produce an "rf off" output signal from the modulator. If the RETRACE selector switch S13 is placed in the ON position, to keep the rf on during the retrace, terminal A5-X is grounded when the FREQUENCY Mode Selector switch S14 is in one of the swept mode positions. This prevents the negative blanking impulse from being applied to keying diodes A5CR3 and A5CR4 so that the rf output (with modulation) remains on during the retrace interval.

In the SINGLE frequency mode, except when external modulation is used, terminal X is grounded to disable the retrace blanking circuit and allow the rf output to be on continuously unless internal square-wave modulation is used. In the OFF frequency mode, terminal X is left open-circuited, so that the retrace blanking signal, which is provided continuously from the disabled sweep generator in this mode, will drive A5Q8 to hold the modulator in the "rf off" condition.

4.15 TRANSFER OSCILLATOR. (See Figure 4-16.)

The transfer oscillator is used as a coupling system to permit both the modulation signal and the dc voltage from the leveler-amplifier (when used) to be transferred to the elevated grid potential of the BWO tube. Accordingly, the input and output of the transfer oscillator must be isolated for at least 2500 V dc, and the circuit is contained on a separate board, A9. The transfer oscillator circuit receives its modulation signal from A5-F on the modulator PC board. This signal will be at 0 V when rf output is desired from the microwave tube, and +11 V when the rf output is to be turned off. This signal is combined with the leveler output in such a way that signals which tend to reduce the rf power level take precedence. Thus, modulated output can be obtained within a leveled envelope.

The circuit consists of a 45-megacycle oscillator (A9Q1), a 45-megacycle oscillator output amplifier and modulator (A9Q2 and A9Q3), a balanced demodulator consisting of a transformer, rectifier, and filter, and the output driver transistor (A9Q4). The current through A9Q4 drives the modulation electrode voltage control transistor A12Q1 in the elevated supply PC board. Circuit component values associated with A12Q1 are selected as necessary to provide the proper control voltage for each microwave tube type and frequency range.

Transistor A9Q1 and the associated L-C circuit components form a shunt-fed Colpitts oscillator. A9C2 is the feedback capacitor. The oscillator output is coupled to amplifier A9Q2 through capacitor A9C6. This output has a constant level, but the 45-mc signal coupled to demodulator transformer A9T1 is varied in proportion to the amount of level-reduction required in the final rf output, through the action of the oscillator output amplifier and modulator, A9Q2 and A9Q3. The output from A9Q2 is developed across A9L4 and coupled to transformer A9T1 by A9C7 and A9C9. The 45-mc signal output level supplied by A9Q2 is dependent upon the conduction of modulator amplifier A9Q3, since this, in turn, determines the positive reference level to which A9L4 is returned. With heavy conduction of A9Q3 (due to a high positive signal applied to its base through A9-3 or A9-4), A9L4 will have a peak-to-peak drop of almost 15 V across it. With A9Q3 cut off, A9L4 will experience a negligible voltage drop, and therefore the 45 mc output signal from A9Q2 will be negligible.

Diodes A9CR1 and A9CR2 act as an adder which allows the more positive of the signals from the modulator (A9-3) or the leveler-amplifier (A9-4) to take control of A9Q3. The operation of both the modulator and leveler are such that a positive signal is supplied to the transfer oscillator when the rf output level is to be reduced. Thus, the 45-mc output signal level developed by A9Q2 is related to the desired amount of reduction in the rf output level.

The two 30-pf, 6000-volt coupling capacitors A9C7 and A9C9 supply the dc isolation between the transfer oscillator input and output circuits. The return line for the output circuit driven by A9T1 is the -100 V supply bus, which is -100 V from cathode potential. The primary of A9T1 is resonated by A9C8

for maximum signal transfer at 45 mc. The output of A9T1 is full-wave rectified by A9CR3 and A9CR4, to provide balanced demodulation without transferring 45-mc signals to the -100 V supply line. The resulting voltage is then filtered by the L-C stages and applied to A9Q4. This A9Q4 drive signal, which appears across A9R4, will be between 0 and +5 volt. It will produce a corresponding current through A9Q4 that varies between 0 and approximately 35 ma. This current is fed to the BWO grid electrode control transistor A12Q1. This causes the BWO grid voltage to vary between 0 and -61 volts (Varian tubes) or between 0 and -25 volts (Stewart tubes) for full-on to full-off control. Components in the A12Q1 output circuit are chosen to achieve the proper range of control voltage when less than the above voltage swing is required. The connection through A12C14 to the 0-line(some units) minimizes transients in the transfer oscillator output when power is switched off.

4.16 FREQUENCY CONTROL SWITCHING. (See Figure 4-17.)

Frequency control switching as it affects each individual circuit has been discussed in previous paragraphs. Figure 4-17 shows a complete functional schematic diagram of switches S14 and S15 with each position identified. It includes a capsule description of the purpose of each functional section, which can be used to obtain a more thorough knowledge of the circuit. For reference in trouble-shooting, the physical arrangement of each switch is also shown in Figure 4-17, with physical contact terminals numbered to agree with the functional schematic. These letter and number designations also agree with those used on the foldout schematics in the rear of this manual. See Paragraph 4.12 for a discussion of sweep frequency control switching.

4.17 MODULATION AND SWEEP CONTROL SWITCHING. (See Figure 4-18.)

For convenience in following the operation of S10, S11, and S12, functional schematics showing connections made in each switch position are given in Figure 4-18. For reference in trouble-shooting, the physical arrangement of each switch is also shown in Figure 4-18, with physical contact terminals numbered to agree with the functional schematic. These letter and number designations also agree with those used on the foldout schematics in the rear of this manual. The functions of each section of S10 and S11 are described in Paragraph 4.11. The functions of each section of S12 are described in Paragraph 4.14.

4.18 DESCRIPTION OF MICROWAVE OSCILLATOR (BWO) TUBE CONTROL CIRCUITS.

A basic block diagram of the circuits which operate the BWO is shown inside the dotted borders in Figure 4-1 (Sheet 2).The major circuit PC Boards are A11, A12, and A13. The Paragraphs which follow describe the BWO and these PC boards in detail.

The backward-wave oscillator (BWO) tube located in the lower left portion of the chassis supplies the sweep oscillator rf output.By applying proper drive signals to the BWO tube,the A12 and A11 PC boards convert the dc power and control signals supplied by the other PC boards described in previous paragraphs, into proper-frequency rf output signals with the required modulation and/or leveling.Power supply drive voltages are standardized for all units where possible; but because of the different cathode and anode biasing requirements of different-frequency BWO tubes, the level-controlling feedback for these two supplies is developed in the elevated supply. Thus, all supply differences between units are confined to the elevated supply.

The cathode supply voltage applied to the BWO tube controls the rf output frequency. The cathode supply output line passes through the Elevated Supply PC Board A12, where it is connected to the 0-line. It then connects directly to the BWO tube cathode. The cathode supply output varies from -150 V to -2500 V, as required to develop sufficient feedback through the diode shaper board to exactly cancel the linear 0 to +15 V frequency-determining control signal developed by the dc control circuits in the Model 650. The Diode Shaper PC Board A13 is shown in Figure 4-1 (Sheet 1).

The diode shaper board monitors a low-voltage replica of the cathode supply output, provided through a string of feedback dropping resistors, within a range of 0 to -15 V. From this, the board develops a non-linear feedback signal which compensates for the non-linear cathode voltage-vs.-output frequency performance curve of the BWO and permits closed-loop frequency control with a linear dial and linear control voltages.

The BWO tube helix operates at near-ground potential, being connected to ground through 10 ohms* (A12R2 in parallel with A7R10), as shown in Figure 4-10. The BWO tube collector** is tied to the +100 V supply through 10-ohm resistor A12R13 in the elevated supply.

The anode supply output line is coupled to the BWO tube through the elevated supply, as shown in Figure 4-11. The elevated supply develops feedback across A12R11, A12R14 to control the anode supply voltage to the level required by each tube. A12R14 is factory selected, and A12R9 is factory-adjusted to set the proper voltage.

The rf output level is controlled by two different methods, grid leveling (Models 64(*)0, 64(*)1, and 64(*)4) or PIN diode leveling (Models 64(*)2, 64(*)3, and 64(*)5).

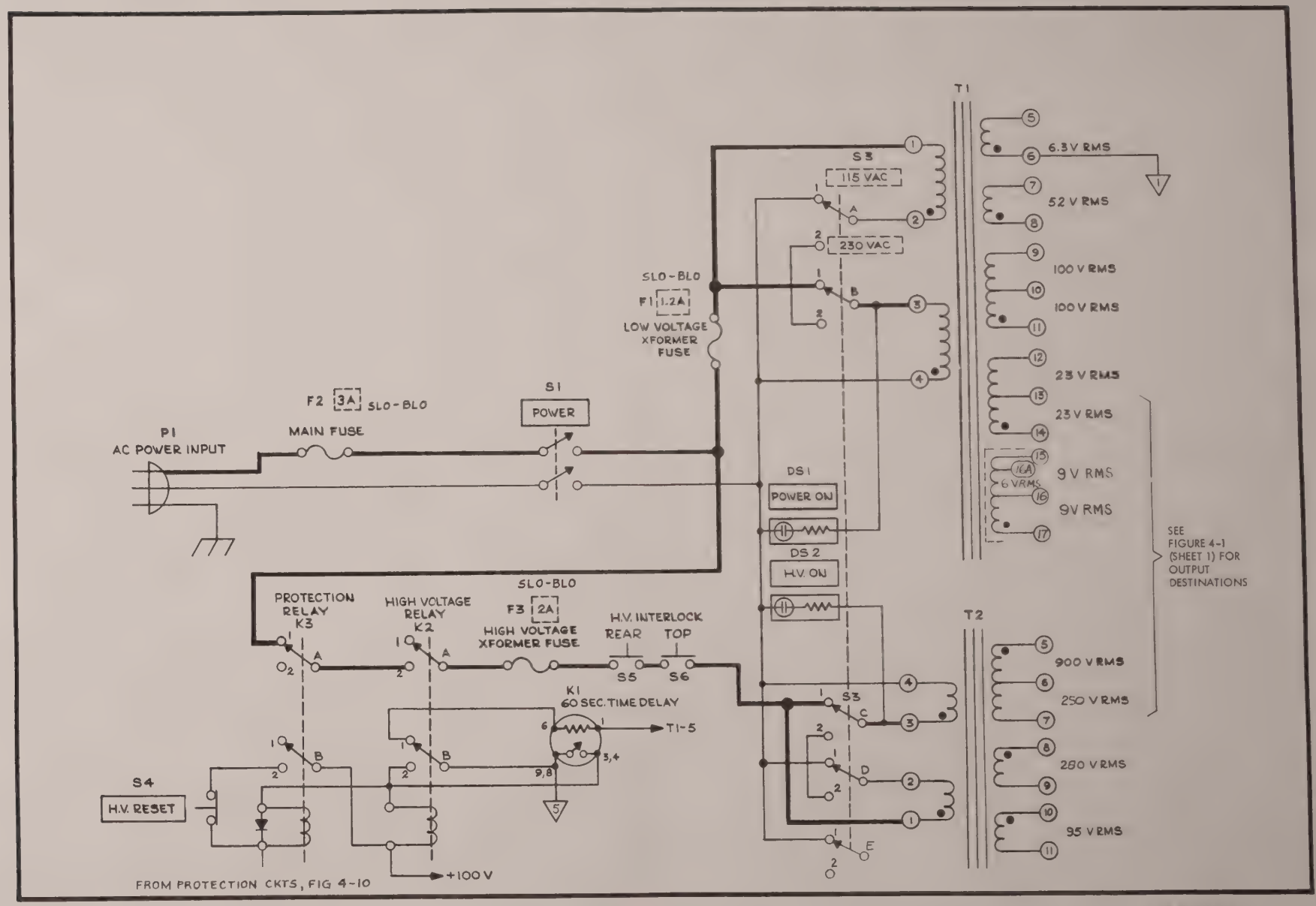
4.18.1 In instruments using grid leveling, the grid voltage applied to the BWO tube control the rf output level. The grid voltage is developed by the circuit of A12Q1 as shown in Figure 4-16. This circuit operates within the range of $V_{cathode}$ and -100 V below $V_{cathode}$. The transfer oscillator supplies zero current drive when no modulation or leveling signal is present. This cuts off A12Q1, bringing the grid close to cathode potential for full rf output power. In this condition, the only drop across A12L1 and A12R3,A12R4,and A12R5 is that due to grid current.

To turn off the rf output during the "off" half-cycle of square wave modulation or during the "rf off" mode, the transfer oscillator generates a current of about 35 ma which develops a drop of 61 V across A12R4 and A12R5 so that the effective grid-cathode bias of the BWO tube is -61 V (Varian tubes) or -25 V (Stewart tubes). This is sufficient to completely cut off the electron beam in the tube, providing an infinite on-off ratio.

For control of output level in the leveled mode, the tube rf output is reduced during the sweep by a variable amount as required to produce constant power equal to that available at the point of minimum unleveled output. The transfer oscillator generates an analog current drive signal related to the amount of level reduction required, ranging from 0 to less than 35 ma. Transistor Q1 then biases the BWO tube grid as necessary to reduce power to the required steady level.

* 100Ω on units having Stewart/WJ BWO tubes.

**Stewart/WJ BWO tubes only.



Model 6400

FIGURE 4-2
PRIMARY POWER DISTRIBUTION

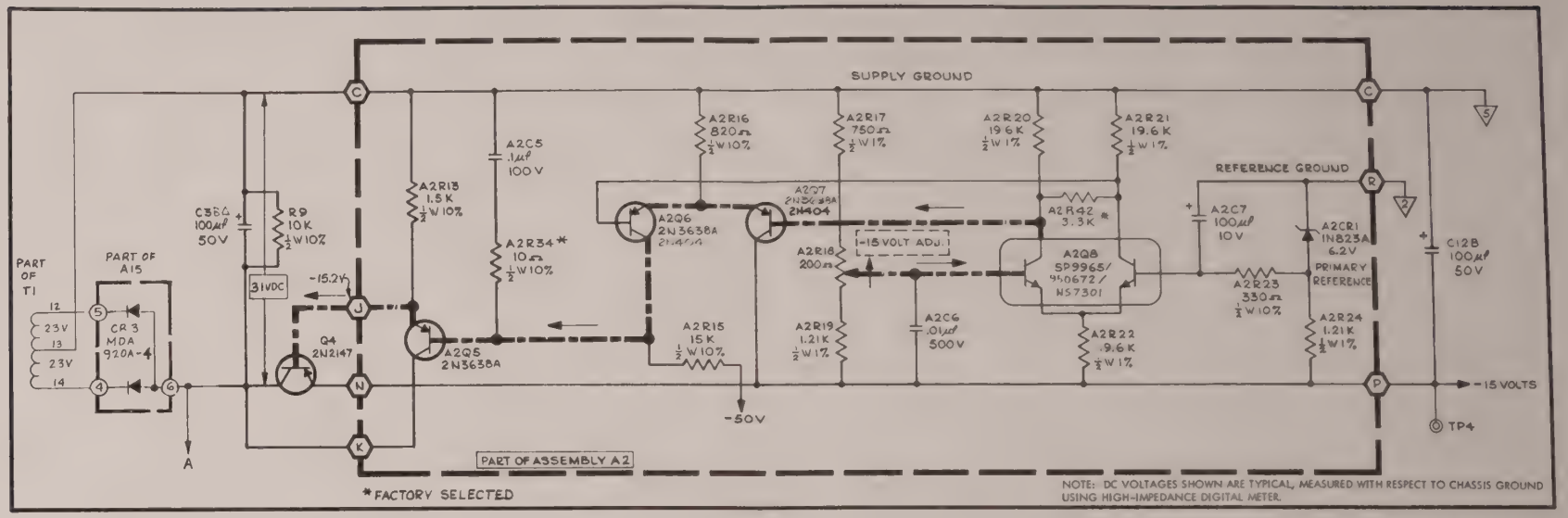


FIGURE 4-3
-15 VOLT SUPPLY

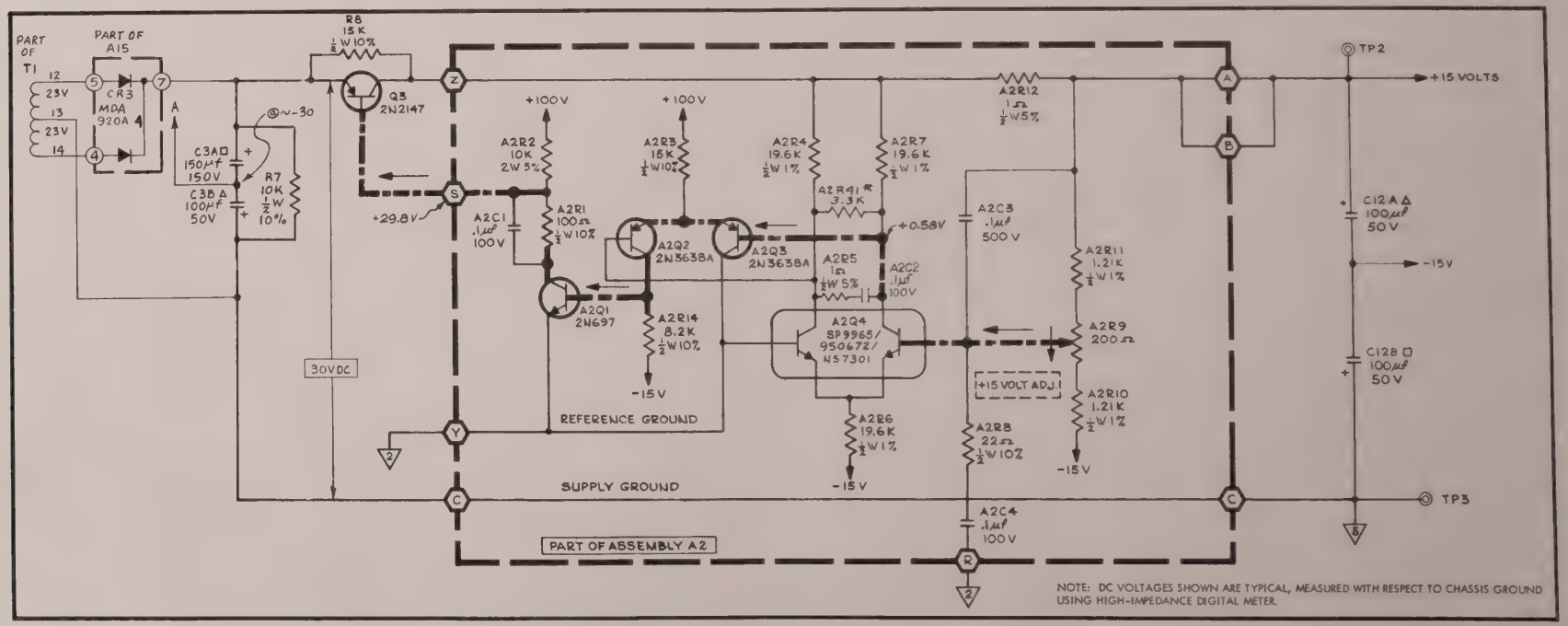


FIGURE 4-4
+15 VOLT SUPPLY

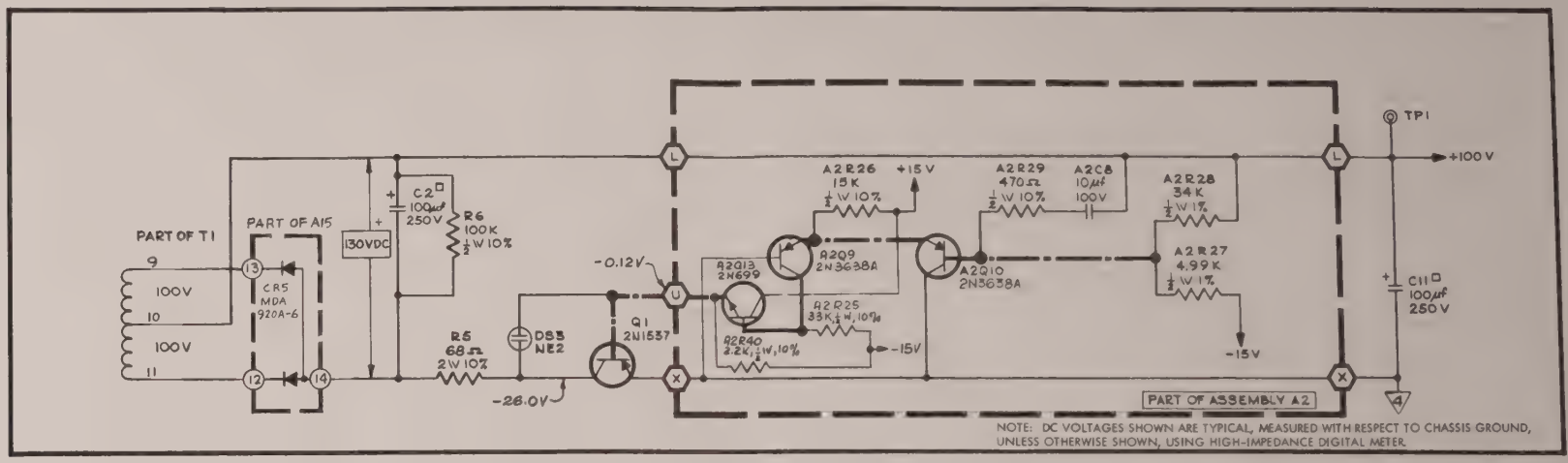


FIGURE 4-5
+100 VOLT SUPPLY

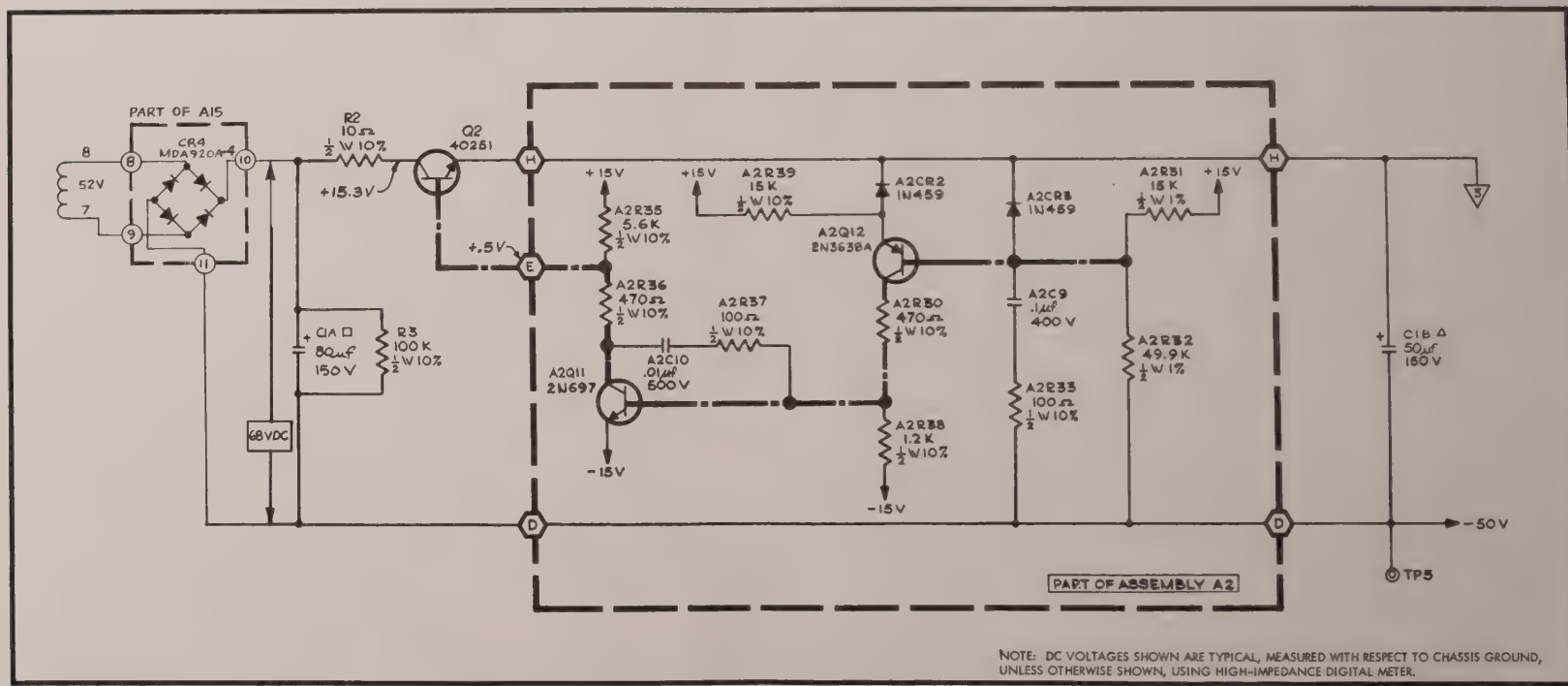


FIGURE 4-6
-50 VOLT SUPPLY

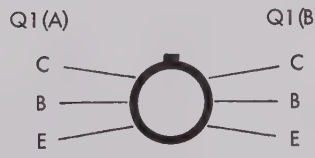
VOLTAGE MEASUREMENTS IN CATHODE SUPPLY MAIN FEEDBACK AMPLIFIER

If voltage measurements in the impedance converter input circuits feeding the Summing Junction indicate proper operation, use the following chart to short individual stages in the high gain amplifier A1Q1 - A1Q7 to isolate the defective stage.

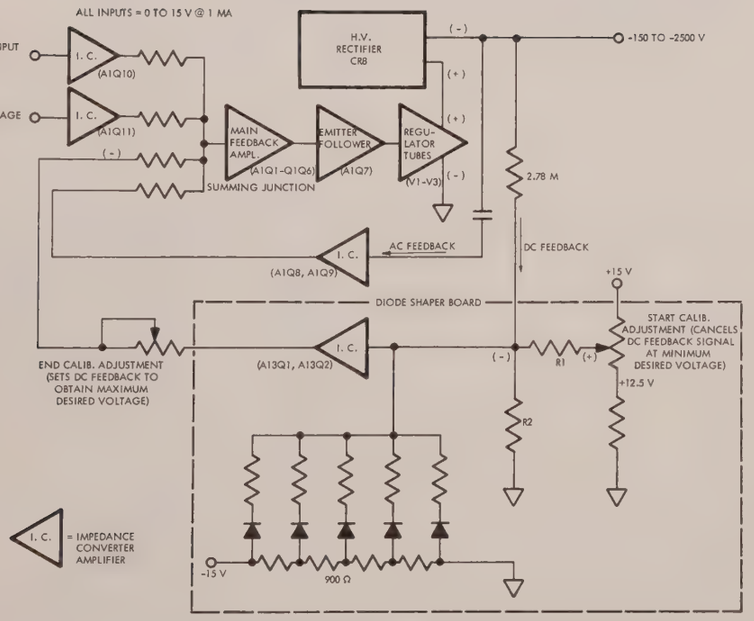
NOTE:
If cathode supply output voltage rests at ≈+105 V (series regulator tubes cut off), start at the middle of chart by shorting the Q4 collector to emitter. If the following stages A1Q5, A1Q6, and A1Q7 are OK, this will turn the series regulator tubes full on to -3KV. This then indicates that the trouble is between A1Q1 and A1Q4. In that case, continue on down the chart until you cannot shift the cathode supply voltage. The trouble is then in the stage being tested or in the one on either side of it.

If shorting Q4 does not turn the cathode supply fully on, then proceed upward on the chart until you reach a stage where you can shift the output E. The trouble then will be in that stage or in the one on either side of it.

SHORTING CONNECTION	SUPPLY OUTPUT	POSSIBLE FAULT IF OUTPUT IS INCORRECT
Q7 B to E	+105 V	open Q7
Q7 C to E	-3 KV	shorted Q7
Q6 B to E	-3 KV	open Q6; shorted Q7; open Q5
C to E	+105V	shorted Q6; shorted Q5
Q5 B to E	-3 KV	open Q5; open Q6; shorted Q4
C to E	+105 V	shorted Q5; shorted Q6
Q4 B to E	+105 V	open Q4; shorted Q5; shorted Q3
C to E	-3 KV	shorted Q4; open Q5; open Q3
Q3 B to E	-3 KV	open Q3; shorted Q4; shorted Q2
C to E	+105 V	shorted Q3; open Q4; open Q2
Q2 B to E	+105 V	open Q2; shorted Q3; shorted Q1B
C to E	-3 KV	shorted Q2; open Q3; open Q1B
Q1B B to E (signal output side)	-3 KV	open Q1B; shorted Q2; shorted Q1A
C to E	+105 V	shorted Q1B; Q2; open Q1A
Q1A B to E (signal input side)	+105 V	open Q1A; shorted Q1B
C to E	-3 KV	shorted Q1A; open Q1B



Q1 { 2N4956/ NS7301/ or (SP9965) as seen from top of board



BLOCK DIAGRAM OF CATHODE SUPPLY

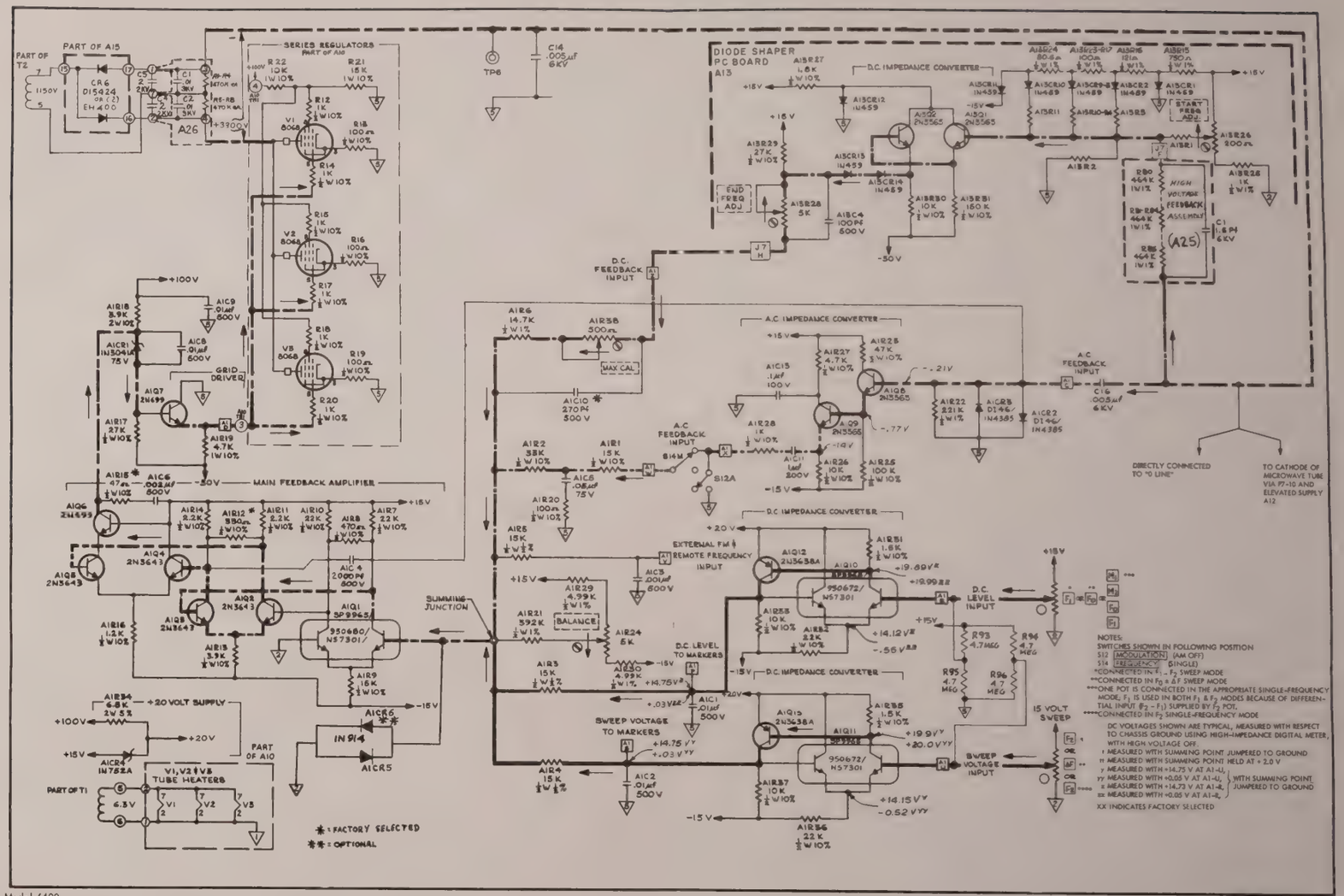

PART OF A15
PART OF T2
CR6 D15424 OR (2) EH400
A26
SERIES REGULATORS PART OF A26
+3900 V
TP6
C14 .005 µf 6KV
DIODE SHAPER PC BOARD A13
D.C. IMPEDANCE CONVERTER
A.C. IMPEDANCE CONVERTER
A25
HIGH VOLTAGE FEEDBACK ASSEMBLY
D.C. FEEDBACK INPUT
A.C. FEEDBACK INPUT
DIRECTLY CONNECTED TO "0 LINE"
TO CATHODE OF MICROWAVE TUBE VIA P7-10 AND ELEVATED SUPPLY A12
MAIN FEEDBACK AMPLIFIER
GRID DRIVER
SUMMING JUNCTION
EXTERNAL FM REMOTE FREQUENCY INPUT
D.C. LEVEL TO MARKERS
SWEEP VOLTAGE TO MARKERS
D.C. LEVEL INPUT
SWEEP VOLTAGE INPUT
15 VOLT SWEEP
+20 VOLT SUPPLY
V1,V2,V3 TUBE HEATERS
PART OF A10
PART OF T1
* = FACTORY SELECTED
** = OPTIONAL
NOTES:
SWITCHES SHOWN IN FOLLOWING POSITION
S12 MODULATION (AM OFF)
S14 FREQUENCY (SINGLE)
*CONNECTED IN F1 - F2 SWEEP MODE
**CONNECTED IN F0 & Δf SWEEP MODE
***ONE POT IS CONNECTED IN THE APPROPRIATE SINGLE-FREQUENCY MODE; F1 IS USED IN BOTH F1 & F2 MODES BECAUSE OF DIFFERENTIAL INPUT (F2 - F1) SUPPLIED BY F2 POT.
****CONNECTED IN F2 SINGLE-FREQUENCY MODE
DC VOLTAGES SHOWN ARE TYPICAL, MEASURED WITH RESPECT TO CHASSIS GROUND USING HIGH-IMPEDANCE DIGITAL METER, WITH HIGH VOLTAGE OFF.
I MEASURED WITH SUMMING POINT JUMPERED TO GROUND
II MEASURED WITH SUMMING POINT HELD AT +2.0 V
x MEASURED WITH +14.75 V AT A1-J4
yy MEASURED WITH +0.05 V AT A1-J4 } WITH SUMMING POINT
z MEASURED WITH +14.73 V AT A1-J4 } JUMPERED TO GROUND
zz MEASURED WITH +0.05 V AT A1-J4
XX INDICATES FACTORY SELECTED

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FIGURE 4-7
CATHODE SUPPLY

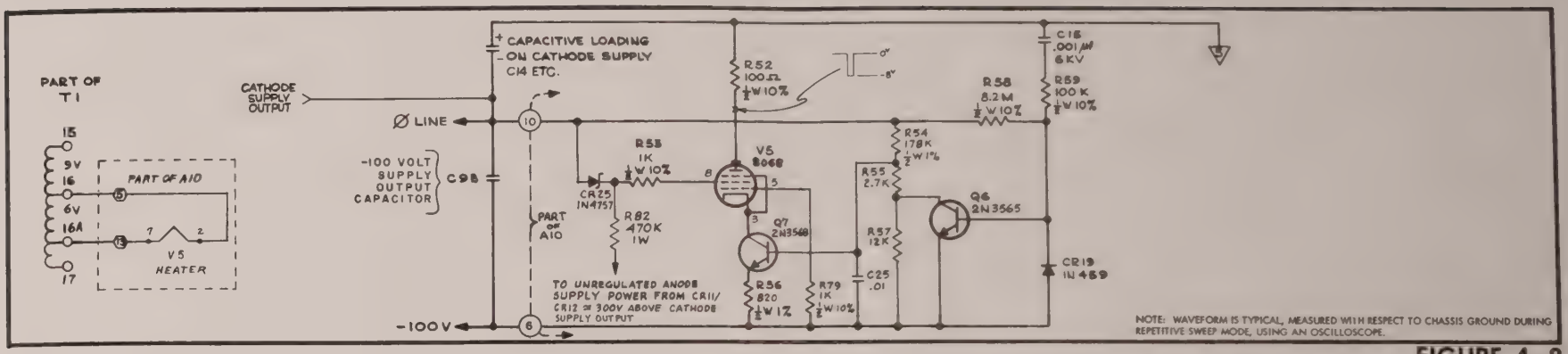


FIGURE 4-8
SWEEP RETRACE DISCHARGE CIRCUIT

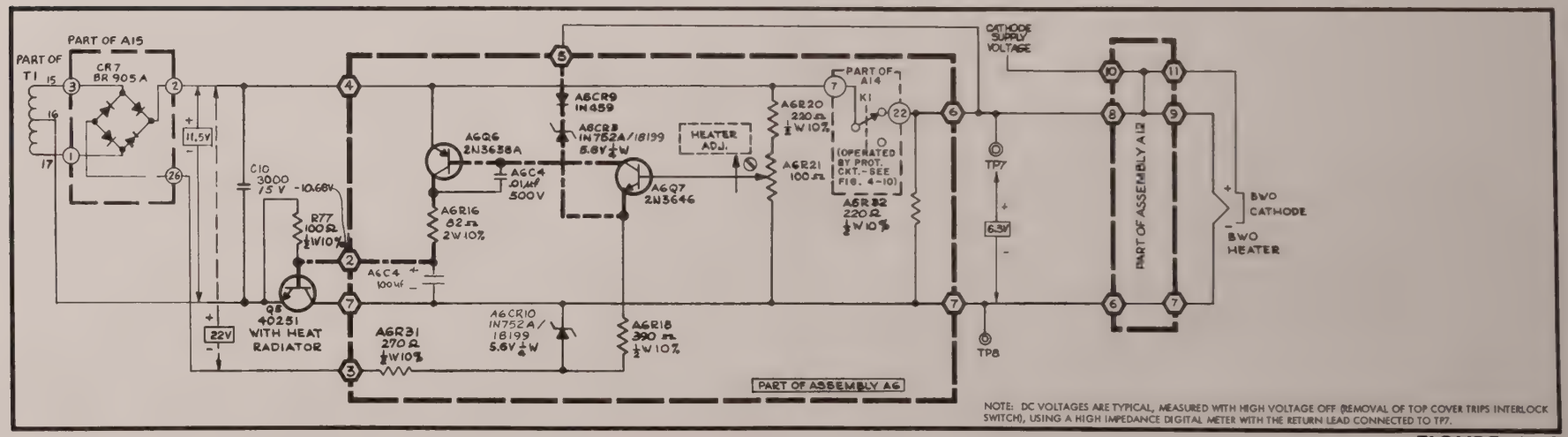


FIGURE 4-9
HEATER SUPPLY

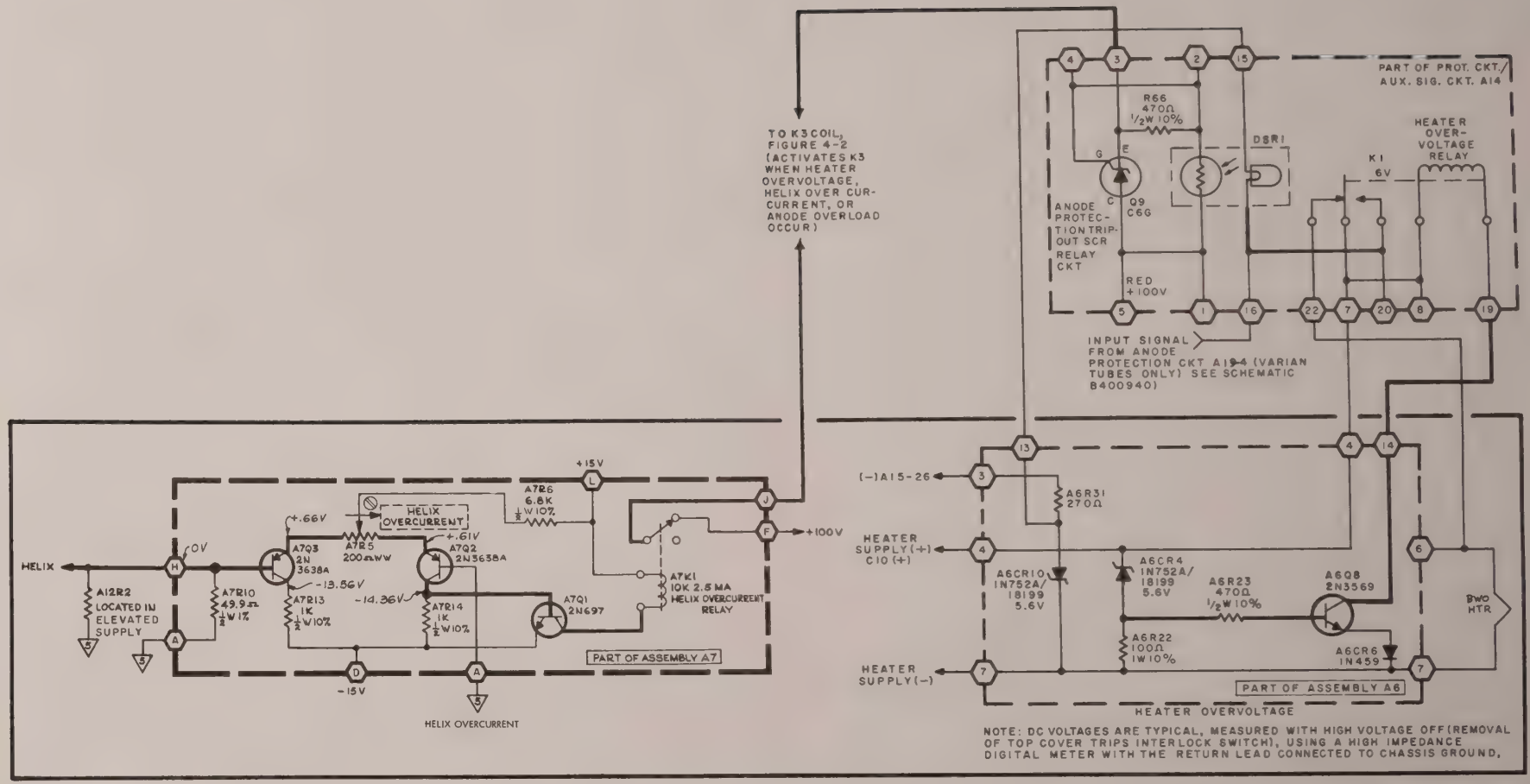

TO K3 COIL, FIGURE 4-2 (ACTIVATES K3 WHEN HEATER OVERVOLTAGE, HELIX OVER CURRENT, OR ANODE OVERLOAD OCCUR)
PART OF PROT. CKT./ AUX. SIG. CKT. A14
R66 470Ω 1/2W 10%
DSR1
HEATER OVER-VOLTAGE RELAY
K1 6V
ANODE PROTECTION TRIP-OUT SCR RELAY CKT
Q9 C6G
RED +100V
INPUT SIGNAL FROM ANODE PROTECTION CKT A1 (VARIAN TUBES ONLY) SEE SCHEMATIC B400940)
+15V
A7R6 6.8K 1/2W 10%
HELIX OVERCURRENT
+.66V
+.61V
A7R5 200 mW
A7Q3 2N 3638A
A7Q2 2N3638A
-13.56V
-14.36V
HELIX
0V
A12R2 LOCATED IN ELEVATED SUPPLY
A7R10 49.9Ω 1/2W 1%
A7R13 1K 1/2W 10%
A7R14 1K 1/2W 10%
A7Q1 2N697
A7K1 10K 2.5 MA HELIX OVERCURRENT RELAY
+100V
PART OF ASSEMBLY A7
-15V
HELIX OVERCURRENT
(-)A15-26
A6R31 270Ω
HEATER SUPPLY (+) C10 (+)
A6CR10 IN752A/ 1N199 5.6V
A6CR4 IN752A/ 1N199 5.6V
A6R23 470Ω 1/2W 10%
A6Q8 2N3569
BWO HTR
A6R22 100Ω 1W 10%
A6CR6 IN459
HEATER SUPPLY (-)
PART OF ASSEMBLY A6
HEATER OVERVOLTAGE
NOTE: DC VOLTAGES ARE TYPICAL, MEASURED WITH HIGH VOLTAGE OFF (REMOVAL OF TOP COVER TRIPS INTERLOCK SWITCH), USING A HIGH IMPEDANCE DIGITAL METER WITH THE RETURN LEAD CONNECTED TO CHASSIS GROUND.

FIGURE 4-10
PROTECTION CIRCUITS

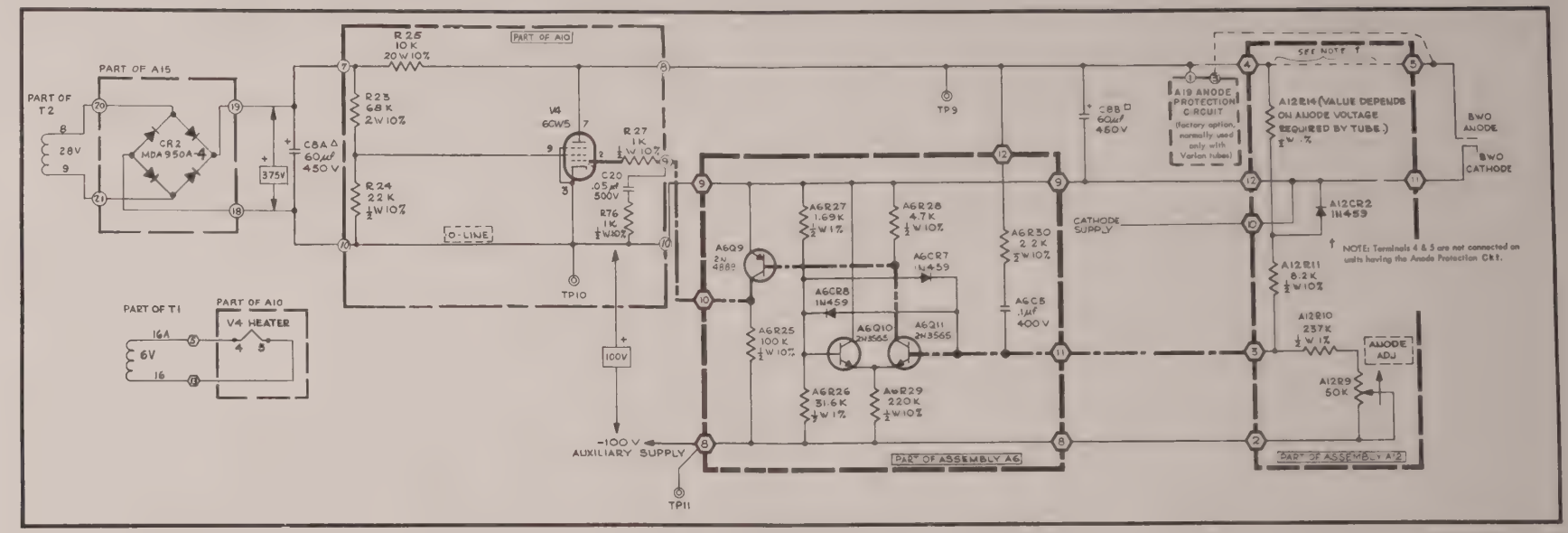


FIGURE 4-11
ANODE SUPPLY

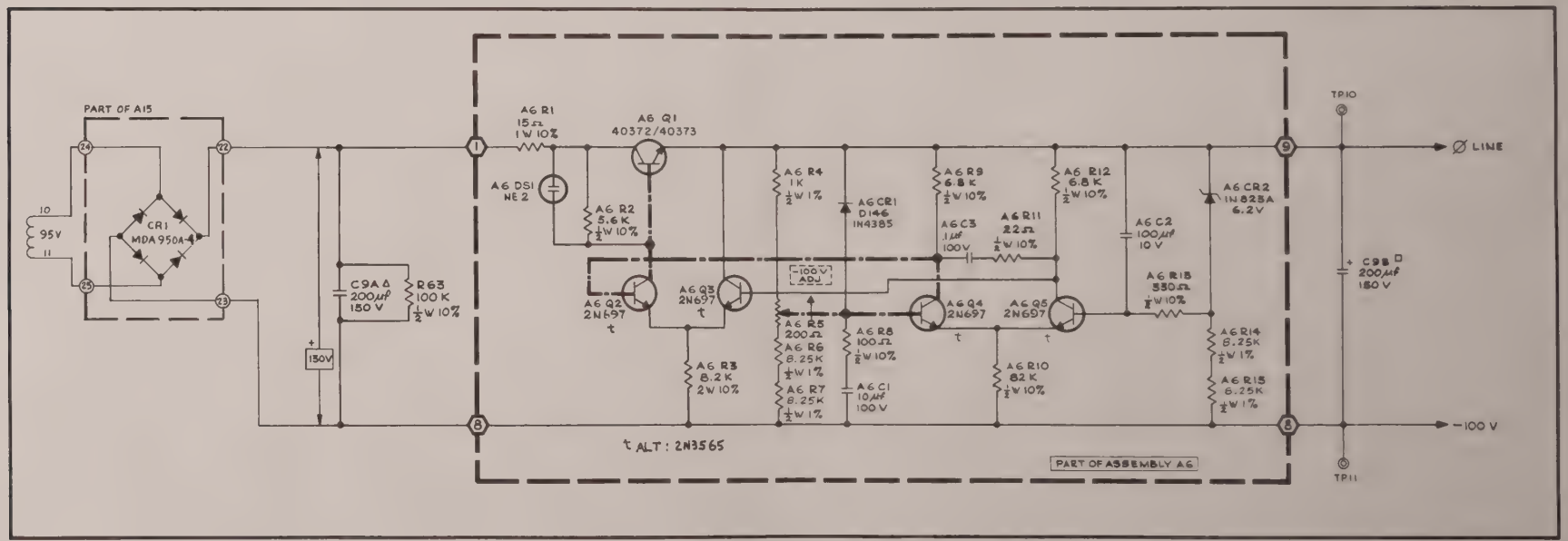
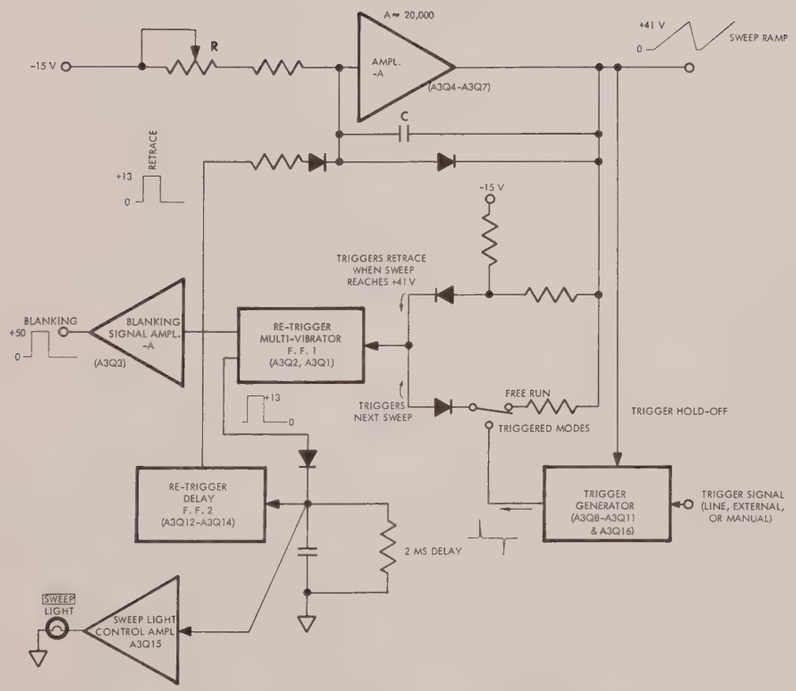


FIGURE 4-12
-100 VOLT SUPPLY



BLOCK DIAGRAM OF SWEEP GENERATOR A3

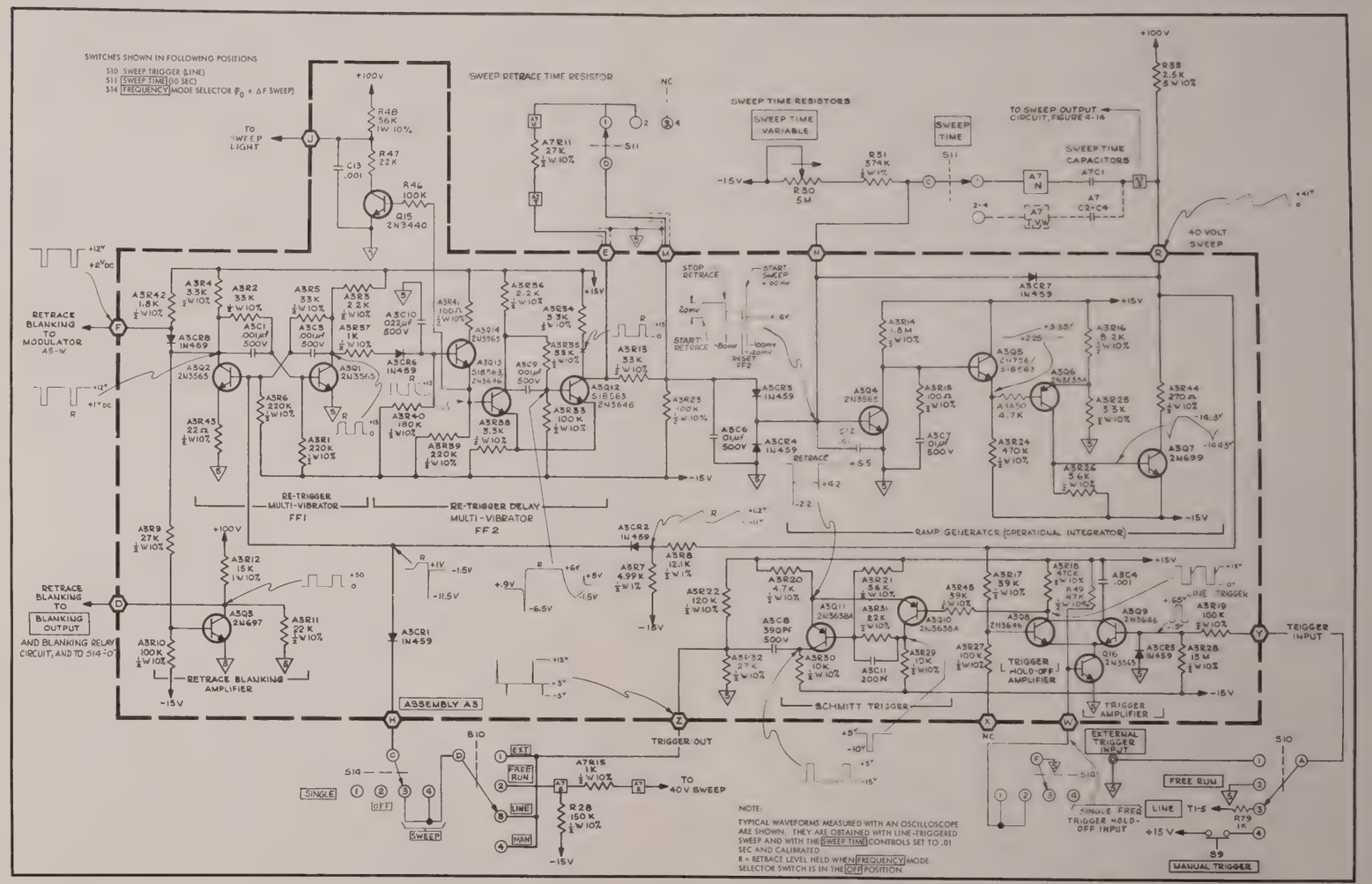

SWITCHES SHOWN IN FOLLOWING POSITIONS
S10 SWEEP TRIGGER (LINE)
S11 SWEEP TIME (10 SEC)
S14 FREQUENCY MODE SELECTOR (F0 ± ΔF SWEEP)
SWEEP RETRACE TIME RESISTOR
SWEEP TIME RESISTORS
SWEEP TIME VARIABLE
SWEEP TIME
SWEEP TIME CAPACITORS
TO SWEEP OUTPUT CIRCUIT, FIGURE 4-14
40 VOLT SWEEP
RETRACE BLANKING TO MODULATOR A5-W
RETRACE BLANKING TO BLANKING OUTPUT AND BLANKING RELAY CIRCUIT, AND TO S14-F
RE-TRIGGER MULTI-VIBRATOR FF1
RE-TRIGGER DELAY MULTI-VIBRATOR FF2
RAMP GENERATOR (OPERATIONAL INTEGRATOR)
RETRACE BLANKING AMPLIFIER
ASSEMBLY A3
SCHMITT TRIGGER
TRIGGER AMPLIFIER
TRIGGER HOLD-OFF AMPLIFIER
TRIGGER INPUT
TRIGGER OUT
EXTERNAL TRIGGER INPUT
LINE TRIGGER
TO 40V SWEEP
SINGLE
OFF
SWEEP
FREE RUN
LINE
MAN
SINGLE FREE
TRIGGER HOLD-OFF INPUT
MANUAL TRIGGER
NOTE:
TYPICAL WAVEFORMS MEASURED WITH AN OSCILLOSCOPE ARE SHOWN. THEY ARE OBTAINED WITH LINE-TRIGGERED SWEEP AND WITH THE SWEEP TIME CONTROLS SET TO .01 SEC AND CALIBRATED.
R = RETRACE LEVEL HELD WHEN FREQUENCY MODE SELECTOR SWITCH IS IN THE OFF POSITION.

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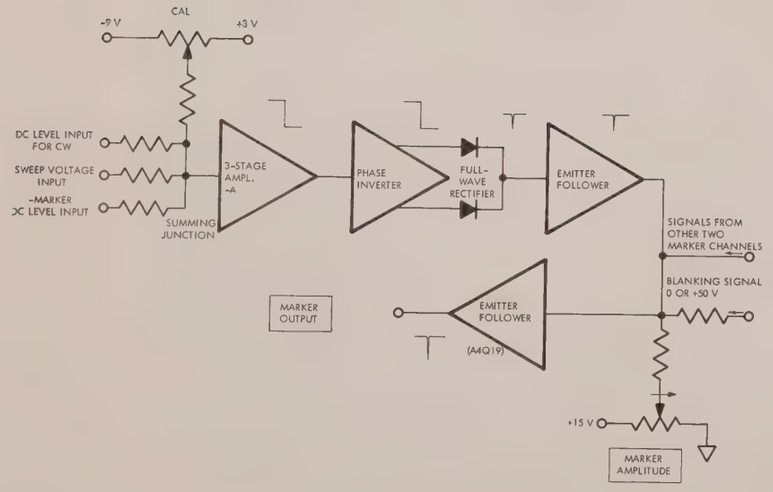
FIGURE 4-13
SWEEP GENERATOR



BLOCK DIAGRAM OF TYPICAL MARKER GENERATOR CHANNEL

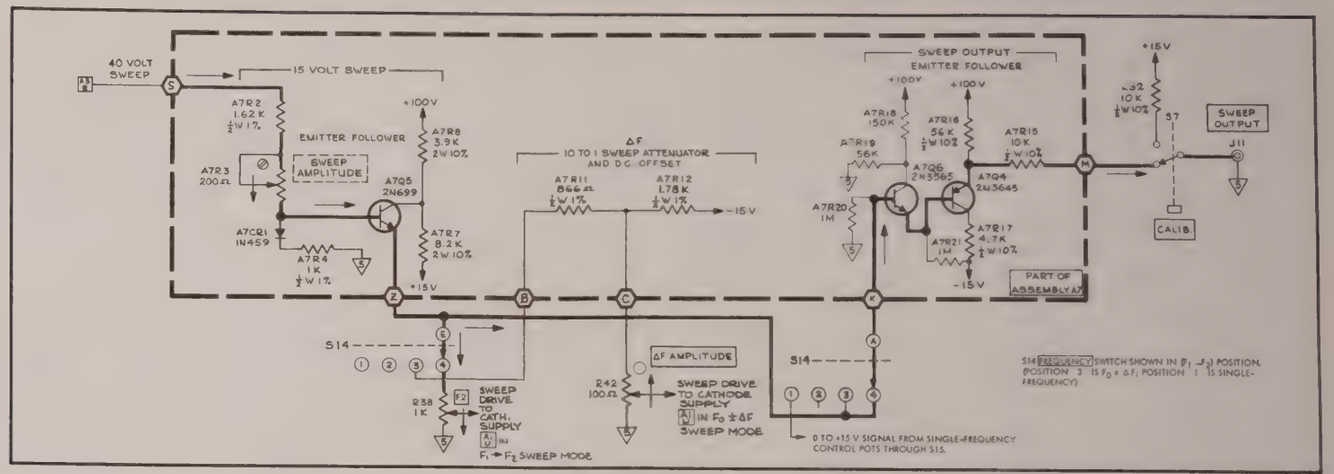
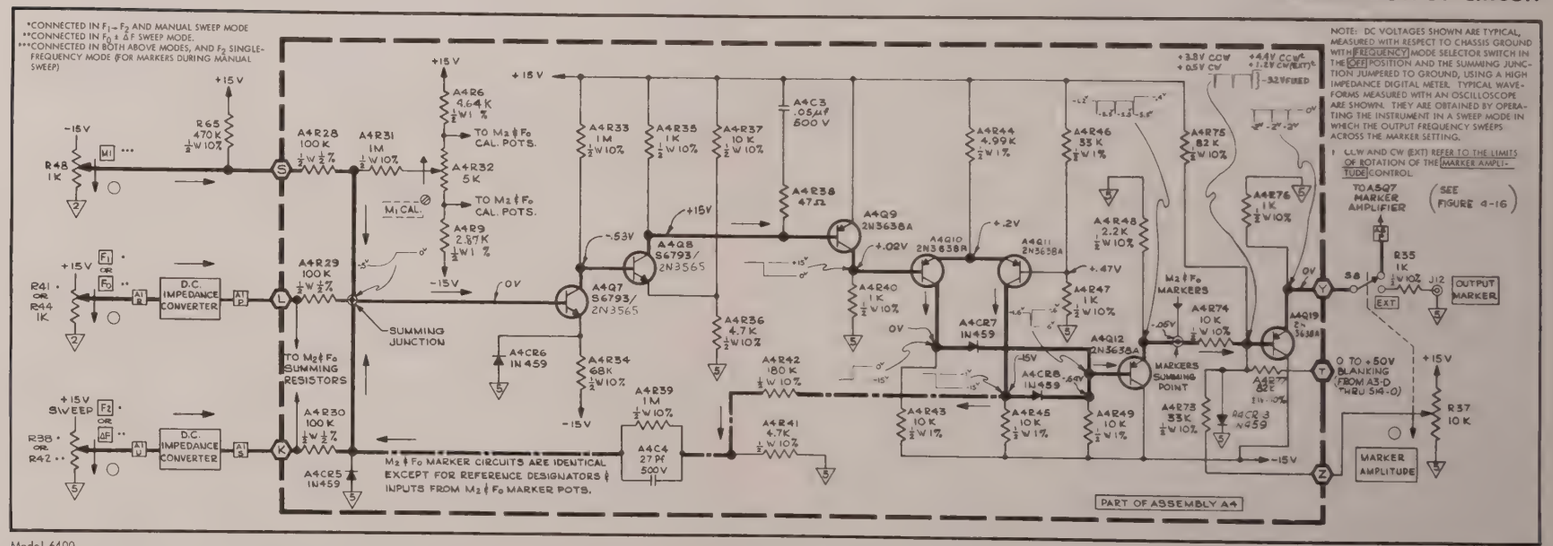
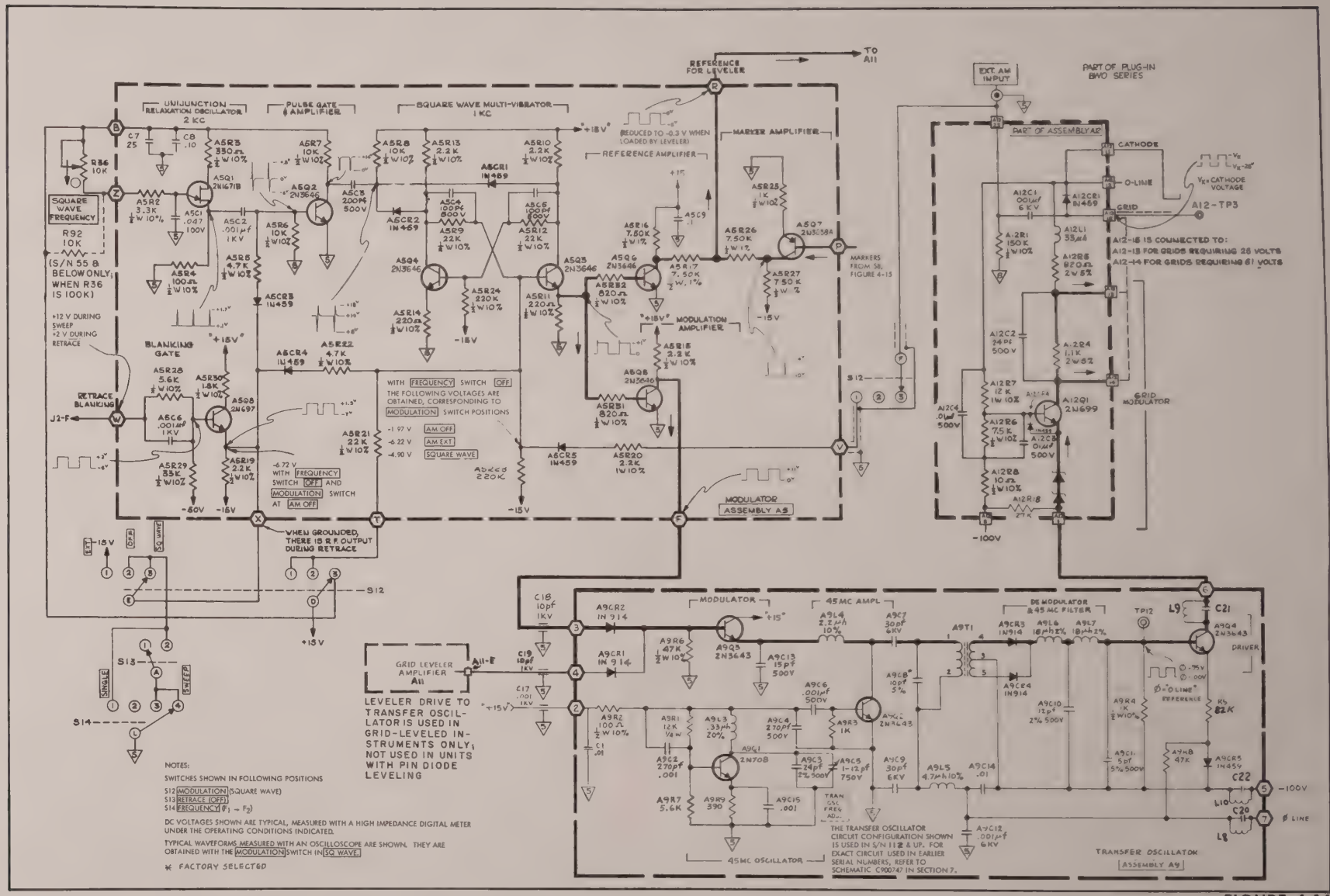

40 VOLT SWEEP
15 VOLT SWEEP
EMITTER FOLLOWER
SWEEP AMPLITUDE
A7R22 1.62 K ½W 1%
A7R23 200 Ω
A7CR1 1N459
A7R4 1 K ½W 1%
A7R8 3.9 K 2W 10%
A7Q5 2N699
A7R7 8.2 K 2W 10%
+100 V
+15 V
ΔF 10 TO 1 SWEEP ATTENUATOR AND D.C. OFFSET
A7R11 866 Ω ½W 1%
A7R12 1.78 K 1W 1%
-15 V
SWEEP OUTPUT EMITTER FOLLOWER
A7R18 150 K
A7R16 56 K ½W 10%
A7R19 56 K
A7Q6 2N3565
A7Q4 2N3645
A7R15 10 K ½W 10%
A7R20 1 M
A7R21 1 M
A7R17 4.7 K ½W 10%
-32 10 K ½W 10%
37
SWEEP OUTPUT
J11
CALIB.
PART OF ASSEMBLY A7
S14
R38 1 K
SWEEP DRIVE TO CATH. SUPPLY
F1 → F2 SWEEP MODE
R42 100 Ω
ΔF AMPLITUDE
SWEEP DRIVE TO CATHODE SUPPLY IN F0 ± ΔF SWEEP MODE
0 TO +15 V SIGNAL FROM SINGLE-FREQUENCY CONTROL POTS THROUGH S15.
S14 FREQUENCY SWITCH SHOWN IN (F1 → F2) POSITION. (POSITION 3 IS F0 ± ΔF; POSITION 1 IS SINGLE-FREQUENCY)

FIGURE 4-14
SWEEP OUTPUT CIRCUIT


*CONNECTED IN F1 → F2 AND MANUAL SWEEP MODE
**CONNECTED IN F0 ± ΔF SWEEP MODE.
***CONNECTED IN BOTH ABOVE MODES, AND F2 SINGLE-FREQUENCY MODE (FOR MARKERS DURING MANUAL SWEEP)
NOTE: DC VOLTAGES SHOWN ARE TYPICAL, MEASURED WITH RESPECT TO CHASSIS GROUND WITH FREQUENCY MODE SELECTOR SWITCH IN THE OFF POSITION AND THE SUMMING JUNCTION JUMPERED TO GROUND, USING A HIGH IMPEDANCE DIGITAL METER. TYPICAL WAVEFORMS MEASURED WITH AN OSCILLOSCOPE ARE SHOWN. THEY ARE OBTAINED BY OPERATING THE INSTRUMENT IN A SWEEP MODE IN WHICH THE OUTPUT FREQUENCY SWEEPS ACROSS THE MARKER SETTING.
1 CLW AND CW (EXT) REFER TO THE LIMITS OF ROTATION OF THE MARKER AMPLITUDE CONTROL.
R48 1 K
R65 470 K ½W 10%
A4R28 100 K
A4R31 1 M ½W 10%
A4R26 4.64 K ½W 1%
TO M2 ∤ F0 CAL. POTS.
A4R32 5 K
A4R9 2.87 K ½W 1%
M1 CAL.
A4R29 100 K
SUMMING JUNCTION
R41 OR R44 1 K
D.C. IMPEDANCE CONVERTER
TO M2 ∤ F0 SUMMING RESISTORS
R38 OR R42
A4R30 100 K
A4CR5 1N459
A4CR6 1N459
A4Q7 S6793/ 2N3565
A4Q8 S6793/ 2N3565
A4R34 68 K ½W 10%
A4R39 1 M ½W 10%
A4C4 27 Pf 500 V
M2 ∤ F0 MARKER CIRCUITS ARE IDENTICAL EXCEPT FOR REFERENCE DESIGNATORS ∤ INPUTS FROM M2 ∤ F0 MARKER POTS.
A4R33 1 M ½W 10%
A4R35 1 K ½W 10%
A4R37 10 K ½W 10%
A4C3 .05 µf 600 V
A4R38 47 Ω
A4R36 4.7 K ½W 10%
A4R42 180 K ½W 10%
A4R41 4.7 K ½W 10%
A4Q9 2N3638A
A4Q10 2N3638A
A4Q11 2N3638A
A4Q12 2N3638A
A4R40 1 K ½W 10%
A4CR7 1N459
A4CR8 1N459
A4R43 10 K ½W 1%
A4R45 10 K ½W 1%
A4R49 10 K ½W 1%
A4R44 4.99 K ½W 1%
A4R46 33 K ½W 1%
A4R48 2.2 K ½W 10%
A4R47 1 K ½W 10%
A4R75 82 K ½W 10%
A4R76 1 K ½W 10%
M2 ∤ F0 MARKERS
A4R74 10 K ½W 10%
MARKERS SUMMING POINT
A4R73 33 K ½W 10%
A4R77 82 E ½W 10%
A4CR3 1N459
A4Q19 2N3638A
TO A5Q7 MARKER AMPLIFIER
(SEE FIGURE 4-16)
R35 1 K ½W 10%
EXT
OUTPUT MARKER
0 TO +50V BLANKING (FROM A5D (THRU SW-D)
R37 10 K
MARKER AMPLITUDE
PART OF ASSEMBLY A4

Model 6400

FIGURE 4-15
MARKER GENERATOR


UNIJUNCTION RELAXATION OSCILLATOR 2 KC
PULSE GATE AMPLIFIER
SQUARE WAVE MULTI-VIBRATOR 1 KC
REFERENCE AMPLIFIER
MARKER AMPLIFIER
MODULATION AMPLIFIER
BLANKING GATE
SQUARE WAVE FREQUENCY
R92 10K
(S/N 55 & BELOW ONLY; WHEN R36 IS 100K)
+12 V DURING SWEEP +2 V DURING RETRACE
RETRACE BLANKING
J2-F
WHEN GROUNDED, THERE IS R.F. OUTPUT DURING RETRACE
WITH FREQUENCY SWITCH OFF THE FOLLOWING VOLTAGES ARE OBTAINED, CORRESPONDING TO MODULATION SWITCH POSITIONS
-1.97 V AM OFF
-6.22 V AM EXT
-4.90 V SQUARE WAVE
-6.72 V WITH FREQUENCY SWITCH OFF AND MODULATION SWITCH AT AM OFF
REFERENCE FOR LEVELER
TO A11
(REDUCED TO -0.3 V WHEN LOADED BY LEVELER)
MARKERS FROM SB, FIGURE 4-15
MODULATOR ASSEMBLY A9
EXT AM INPUT
PART OF PLUG-IN 8WO SERIES
PART OF ASSEMBLY A12
CATHODE
O-LINE
GRID
A12-TP3
A12-18 IS CONNECTED TO:
A12-13 FOR GRIDS REQUIRING 28 VOLTS
A12-14 FOR GRIDS REQUIRING 61 VOLTS
GRID MODULATOR
-100V
S12
S13
S14
SINGLE
SWEEP
GRID LEVELER AMPLIFIER A11
A11-E
LEVELER DRIVE TO TRANSFER OSCILLATOR IS USED IN GRID-LEVELED INSTRUMENTS ONLY; NOT USED IN UNITS WITH PIN DIODE LEVELING
MODULATOR
45MC AMPL
DEMODULATOR & 45MC FILTER
DRIVER
O LINE REFERENCE
45MC OSCILLATOR
THE TRANSFER OSCILLATOR CIRCUIT CONFIGURATION SHOWN IS USED IN S/N 1132 & UP. FOR EXACT CIRCUIT USED IN EARLIER SERIAL NUMBERS, REFER TO SCHEMATIC C900747 IN SECTION 7.
TRANSFER OSCILLATOR ASSEMBLY A9
NOTES:
SWITCHES SHOWN IN FOLLOWING POSITIONS
S12 MODULATION (SQUARE WAVE)
S13 RETRACE (OFF)
S14 FREQUENCY (F1 → F2)
DC VOLTAGES SHOWN ARE TYPICAL, MEASURED WITH A HIGH IMPEDANCE DIGITAL METER UNDER THE OPERATING CONDITIONS INDICATED.
TYPICAL WAVEFORMS MEASURED WITH AN OSCILLOSCOPE ARE SHOWN. THEY ARE OBTAINED WITH THE MODULATION SWITCH IN SQ WAVE.
* FACTORY SELECTED

Model 6400

FIGURE 4-16
MODULATOR AND TRANSFER OSCILLATOR CIRCUITS

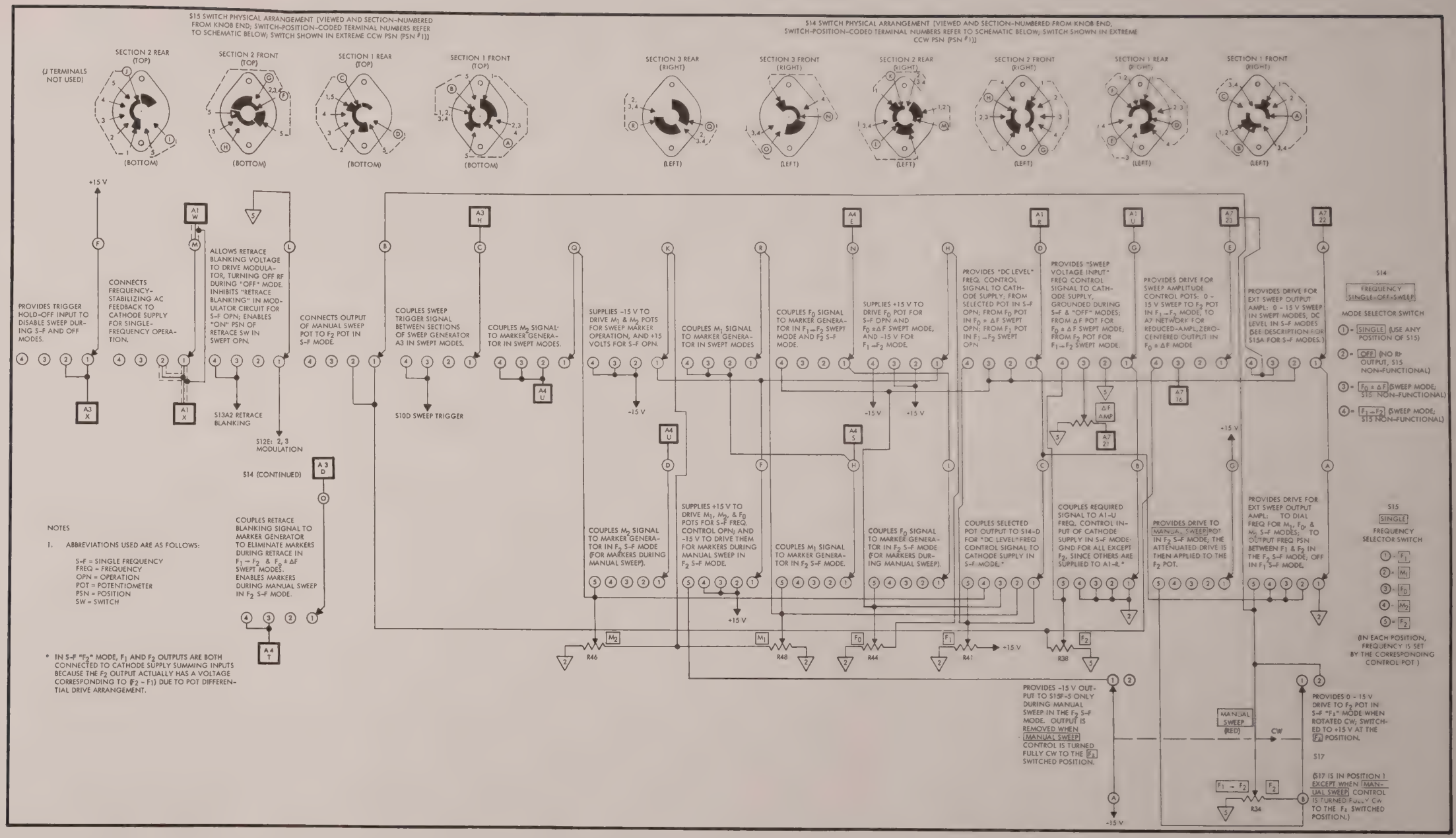

S15 SWITCH PHYSICAL ARRANGEMENT (VIEWED AND SECTION-NUMBERED FROM KNOB END; SWITCH-POSITION-CODED TERMINAL NUMBERS REFER TO SCHEMATIC BELOW; SWITCH SHOWN IN EXTREME CCW PSN (PSN #1))
S14 SWITCH PHYSICAL ARRANGEMENT (VIEWED AND SECTION-NUMBERED FROM KNOB END; SWITCH-POSITION-CODED TERMINAL NUMBERS REFER TO SCHEMATIC BELOW; SWITCH SHOWN IN EXTREME CCW PSN (PSN #1))
(J TERMINALS NOT USED)
SECTION 2 REAR (TOP)
SECTION 2 FRONT (TOP)
SECTION 1 REAR (TOP)
SECTION 1 FRONT (TOP)
SECTION 3 REAR (RIGHT)
SECTION 3 FRONT (RIGHT)
SECTION 2 REAR (RIGHT)
SECTION 2 FRONT (RIGHT)
SECTION 1 REAR (RIGHT)
SECTION 1 FRONT (RIGHT)
(BOTTOM)
(LEFT)
+15 V
PROVIDES TRIGGER HOLD-OFF INPUT TO DISABLE SWEEP DURING S-F AND OFF MODES.
CONNECTS FREQUENCY-STABILIZING AC FEEDBACK TO CATHODE SUPPLY FOR SINGLE-FREQUENCY OPERATION.
ALLOWS RETRACE BLANKING VOLTAGE TO DRIVE MODULATOR, TURNING OFF RF DURING "OFF" MODE. INHIBITS "RETRACE BLANKING" IN MODULATOR CIRCUIT FOR S-F OPN; ENABLES "ON" PSN OF RETRACE SW IN SWEPT OPN.
CONNECTS OUTPUT OF MANUAL SWEEP POT TO F_2 POT IN S-F MODE.
COUPLES SWEEP TRIGGER SIGNAL BETWEEN SECTIONS OF SWEEP GENERATOR A3 IN SWEPT MODES.
COUPLES M_2 SIGNAL TO MARKER GENERATOR IN SWEPT MODES.
SUPPLIES -15 V TO DRIVE M_1 & M_2 POTS FOR SWEEP MARKER OPERATION, AND +15 VOLTS FOR S-F OPN.
COUPLES M_1 SIGNAL TO MARKER GENERATOR IN SWEPT MODES
COUPLES F_0 SIGNAL TO MARKER GENERATOR IN $F_1 - F_2$ SWEPT MODE AND F_2 S-F MODE.
SUPPLIES +15 V TO DRIVE F_0 POT FOR S-F OPN AND $F_0 \pm \Delta F$ SWEPT MODE, AND -15 V FOR $F_1 - F_2$ MODE.
PROVIDES "DC LEVEL" FREQ. CONTROL SIGNAL TO CATHODE SUPPLY; FROM SELECTED POT IN S-F OPN; FROM F_0 POT IN $F_0 \pm \Delta F$ SWEPT OPN; FROM F_1 POT IN $F_1 - F_2$ SWEPT OPN.
PROVIDES "SWEEP VOLTAGE INPUT" FREQ CONTROL SIGNAL TO CATHODE SUPPLY, GROUNDED DURING S-F & "OFF" MODES; FROM ΔF POT FOR $F_0 \pm \Delta F$ SWEPT MODE; FROM F_2 POT FOR $F_1 - F_2$ SWEPT MODE.
PROVIDES DRIVE FOR SWEEP AMPLITUDE CONTROL POTS: 0 - 15 V SWEEP TO F_2 POT IN $F_1 - F_2$ MODE, TO A7 NETWORK FOR REDUCED-AMPL, ZERO-CENTERED OUTPUT IN $F_0 \pm \Delta F$ MODE
PROVIDES DRIVE FOR EXT SWEEP OUTPUT AMPL: 0 - 15 V SWEEP IN SWEPT MODES, DC LEVEL IN S-F MODES (SEE DESCRIPTION FOR S15A FOR S-F MODES.)
S14
FREQUENCY SINGLE-OFF-SWEEP
MODE SELECTOR SWITCH
1 = SINGLE (USE ANY POSITION OF S15)
2 = OFF (NO RF OUTPUT, S15 NON-FUNCTIONAL)
3 = $F_0 \pm \Delta F$ SWEEP MODE; S15 NON-FUNCTIONAL)
4 = $F_1 - F_2$ SWEEP MODE; S15 NON-FUNCTIONAL)
S13A2 RETRACE BLANKING
S10D SWEEP TRIGGER
S12E: 2, 3 MODULATION
S14 (CONTINUED)
COUPLES RETRACE BLANKING SIGNAL TO MARKER GENERATOR TO ELIMINATE MARKERS DURING RETRACE IN $F_1 \rightarrow F_2$ & $F_1 \pm \Delta F$ SWEPT MODES. ENABLES MARKERS DURING MANUAL SWEEP IN F_2 S-F MODE.
COUPLES M_2 SIGNAL TO MARKER GENERATOR IN F_2 S-F MODE (FOR MARKERS DURING MANUAL SWEEP).
SUPPLIES +15 V TO DRIVE M_1, M_2, & F_0 POTS FOR S-F FREQ. CONTROL OPN; AND -15 V TO DRIVE THEM FOR MARKERS DURING MANUAL SWEEP IN F_2 S-F MODE.
COUPLES M_1 SIGNAL TO MARKER GENERATOR IN F_2 S-F MODE.
COUPLES F_0 SIGNAL TO MARKER GENERATOR IN F_2 S-F MODE (FOR MARKERS DURING MANUAL SWEEP).
COUPLES SELECTED POT OUTPUT TO S14-D FOR "DC LEVEL" FREQ CONTROL SIGNAL TO CATHODE SUPPLY IN S-F MODE.*
COUPLES REQUIRED SIGNAL TO A1-U FREQ. CONTROL INPUT OF CATHODE SUPPLY IN S-F MODE: GND FOR ALL EXCEPT F_2, SINCE OTHERS ARE SUPPLIED TO A1-R.*
PROVIDES DRIVE TO MANUAL SWEEP POT IN F_2 S-F MODE; THE ATTENUATED DRIVE IS THEN APPLIED TO THE F_2 POT.
PROVIDES DRIVE FOR EXT SWEEP OUTPUT AMPL: TO DIAL FREQ FOR M_1, F_0, & M_2 S-F MODES; TO OUTPUT FREQ PSN BETWEEN F_1 & F_2 IN THE F_2 S-F MODE; OFF IN F_1 S-F MODE.
S15
SINGLE
FREQUENCY SELECTOR SWITCH
1 - F_1
2 - M_1
3 - F_0
4 - M_2
5 = F_2
(IN EACH POSITION, FREQUENCY IS SET BY THE CORRESPONDING CONTROL POT.)
PROVIDES -15 V OUTPUT TO S15F-5 ONLY DURING MANUAL SWEEP IN THE F_2 S-F MODE. OUTPUT IS REMOVED WHEN MANUAL SWEEP CONTROL IS TURNED FULLY CW TO THE F_2 SWITCHED POSITION.
MANUAL SWEEP (RED)
CW
PROVIDES 0 - 15 V DRIVE TO F_2 POT IN S-F "F_2" MODE WHEN ROTATED CW; SWITCHED TO +15 V AT THE F_2 POSITION.
S17
(S17 IS IN POSITION 1 EXCEPT WHEN MANUAL SWEEP CONTROL IS TURNED FULLY CW TO THE F_2 SWITCHED POSITION.)
NOTES
1. ABBREVIATIONS USED ARE AS FOLLOWS:
S-F = SINGLE FREQUENCY
FREQ = FREQUENCY
OPN = OPERATION
POT = POTENTIOMETER
PSN = POSITION
SW = SWITCH
* IN S-F "F_2" MODE, F_1 AND F_2 OUTPUTS ARE BOTH CONNECTED TO CATHODE SUPPLY SUMMING INPUTS BECAUSE THE F_2 OUTPUT ACTUALLY HAS A VOLTAGE CORRESPONDING TO ($F_2 - F_1$) DUE TO POT DIFFERENTIAL DRIVE ARRANGEMENT.

FIGURE 4-17. SCHEMATIC AND WIRING DIAGRAM OF FREQUENCY MODE SELECTOR SWITCH S14 AND SINGLE FREQUENCY SELECTOR SWITCH S15

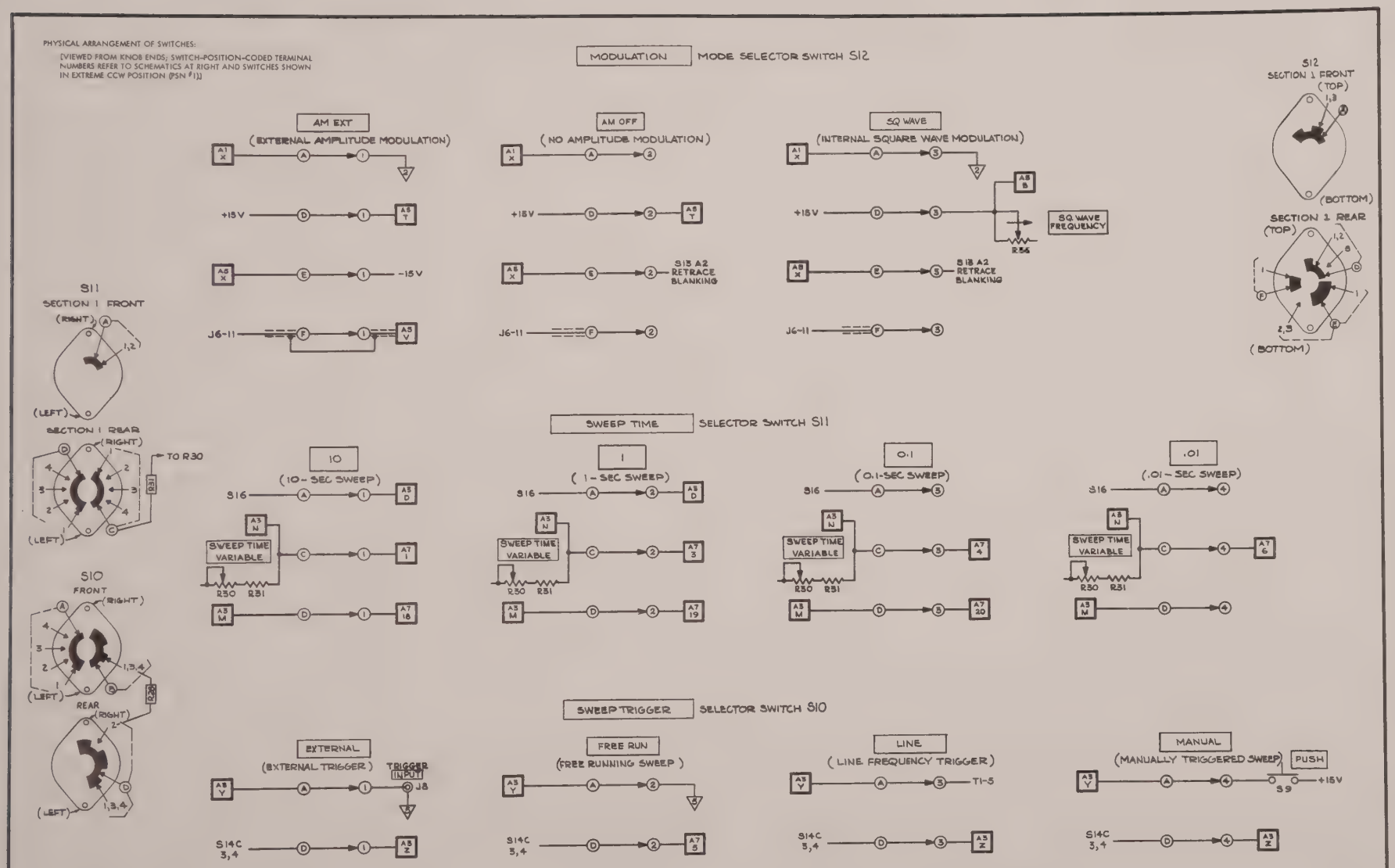


FIGURE 4-18. SCHEMATIC AND WIRING DIAGRAM OF MODULATION, SWEEP TIME AND SWEEP TRIGGER SELECTOR SWITCHES

The Leveler-Amplifier PC Board A11 generates the level-correction control signal for the transfer oscillator in leveled operation. It receives a fixed-level reference signal from the modulator, and a signal proportional to the instantaneous output level from the internal or external sampler. The reference signal level from the modulator can be adjusted by the POWER LEVEL control to achieve balance with the sampler signal at the desired rf power level. The reference signal drops to zero when modulation is simultaneously applied to the BWO tube, to prevent the leveler from attempting to correct for such desired modulation.

4.18.2 In instruments using PIN diode leveling, it is used in combination with BWO grid control for on-off modulation, as shown in Figure 4-19. A solid-state leveler (PIN diode attenuator), driven by the Leveler-Amplifier PC Board A11 is used to provide variable attenuation in the rf output signal path to compensate for power level variations in the unleveled power output characteristic of the BWO tube. The PIN diode attenuator is also used to adjust over-all output power level in both the leveled and unleveled modes. Grid modulation of the BWO tube is used to provide full on-off rf output control for square-wave or pulse modulation. Since the PIN diode attenuator is used for all variable-level power control while the BWO tube continues to operate at full power, maximum frequency stability is achieved.

The grid voltage applied to the BWO tube controls the on-off rf output modulation. The grid voltage is developed by the circuit of A12Q1, just as in grid-leveled instruments.
For control of output level in the leveled mode, the output is attenuated during the sweep by a variable amount as required to produce constant power equal to or less than that available at the point of minimum unleveled output. The leveler-amplifier receives a fixed-level reference signal from the modulator, which is adjusted by the POWER LEVEL control, and a feedback signal proportional to the instantaneous output level from the crystal detector of the internal or external sampler. The leveler-amplifier generates an analog (-) voltage signal for the PIN diode attenuator, related to the amount of level reduction required. This signal is applied to the PIN diode driver circuit which is an integral part of the PIN diode attenuator module. The driver supplies control currents to the leveling and matching diodes contained in the PIN attenuator structure. This rf structure then operates as an electrically-controlled microwave resistor, providing attenuation as necessary to reduce power to the required steady level.

The reference signal level from the modulator is altered only when modulation is simultaneously applied to the BWO tube, to prevent the leveler from attempting to correct for such desired modulation.The POWER LEVEL control adjusts this reference signal to achieve balance with the output from the crystal detector at the desired rf power level. This level may be set anywhere between the maximum output level (above full-band leveling) and 10 db below the maximum level available with full-band leveling, an over-all range of about 15 db.

4.19 THE BACKWARD WAVE OSCILLATOR TUBE. (See Figure 4-20.)

The backward-wave oscillator (BWO) tube is a voltage-tunable microwave oscillator vacuum tube. It consists of an electron gun, a slow wave structure (helix), and a collector at the far end of the slow wave structure. The rf output of the tube is produced by the interaction between the electron beam passing from the gun to the collector end and the electromagnetic field of a microwave signal developed on the slow wave structure. In Stewart tubes the collector collects all electron beam current not intercepted by the helix. In Varian BWO tubes, an ion collector is located at the target end of the slow wave structure. The helix collects all electron current in the tube since there is no electron collecting electrode at the target end of the tube. The ion collector electrode, internally connected to the cathode, is provided to collect positive ions and establish a field gradient that drives the electron current outward for interception by the helix.

Surrounding the evacuated envelope of the tube is a cylindrical permanent magnet which produces a strong axial field. This field focuses the electrons in the beam and allows movement only in the direction of the axis of the tube.

An exterior housing completely covers the magnet and tube, and no magnet adjustments are possible. The tube electrodes are connected to wire leads which are brought out through the housing for connection to the Elevated Supply PC Board A12.

The Stewart tube electron gun contains a heated cathode and two or more aperture disc type control electrodes (grid and anode) which help form the beam and control beam density. The Varian tube electron gun contains a cathode surrounded by an aperture disc control electrode (the grid), and two screen-type electrodes (the anodes) which accelerate, control, and form the beam. $Anode_1$ is brought out to an external connection. $Anode_2$ is internally connected to the helix. The heater is a helical coil contained inside the cathode support cylinder.

In a helix backward wave oscillator, it is desirable to have a hollow cylindrical electron beam since only the electrons that pass adjacent to the helix are fully effective in delivering energy to the wave. Electrons near the middle of the beam consume anode power but contribute little or nothing to the energy interchange that produces the backward wave oscillations. The electron gun elements are arranged to generate a hollow, circular electron beam. The magnetic field, which restricts the electrons to axial movement, then maintains the same geometry to achieve a hollow cylindrical beam throughout the length of the slow-wave structure.

The Stewart tube uses a sleeve-type cathode. In the Varian tube, the emitting portion of the cathode is a hollow cylinder having an L-shaped cross section to absorb the full radiant output of the heater and emit a thin, hollow, cylindrical electron beam having a diameter slightly less than that of the helix. The cold cathode, with a T-shaped cross-section, is fabricated from a non-emitting material and fills the remaining end surface of the cathode cylinder. The grid control field is developed between the cathode and grid disc, just outside the hot cathode ring. This provides effective control of the electron beam right at the emitting surface. The $anode_1$ voltage is maintained at a fixed positive level with respect to the cathode supply, so that the beam emitted from the electron gun does not change appreciably as the cathode voltage is changed to shift the operating frequency. (Since the anodes are of an intercepting type, care must be exercised not to apply too high a voltage or to permit too high a current.)

The helix is a slow-wave structure equal in length to several wavelengths of the lowest output frequency. Thus, the operating frequency range of a particular backward wave oscillator tube is primarily determined by the dimensions of the helix.

It is well known that a slow wave structure will propagate a particular range of frequencies at constant axial velocity (the non-dispersive region) and above that range, the axial velocity of propagation increases with frequency (the dispersive region). The backward wave oscillator operates in the disper-

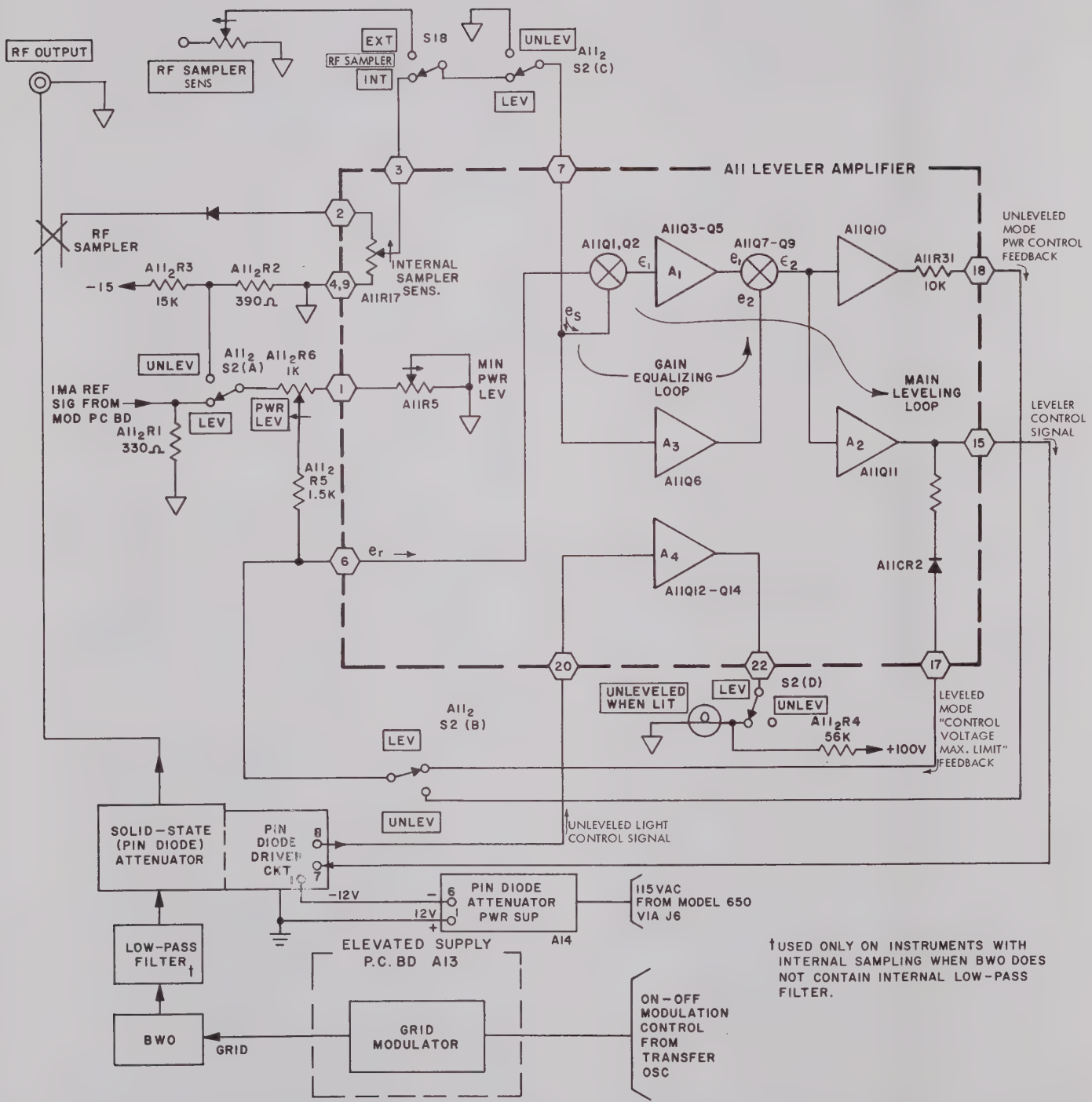
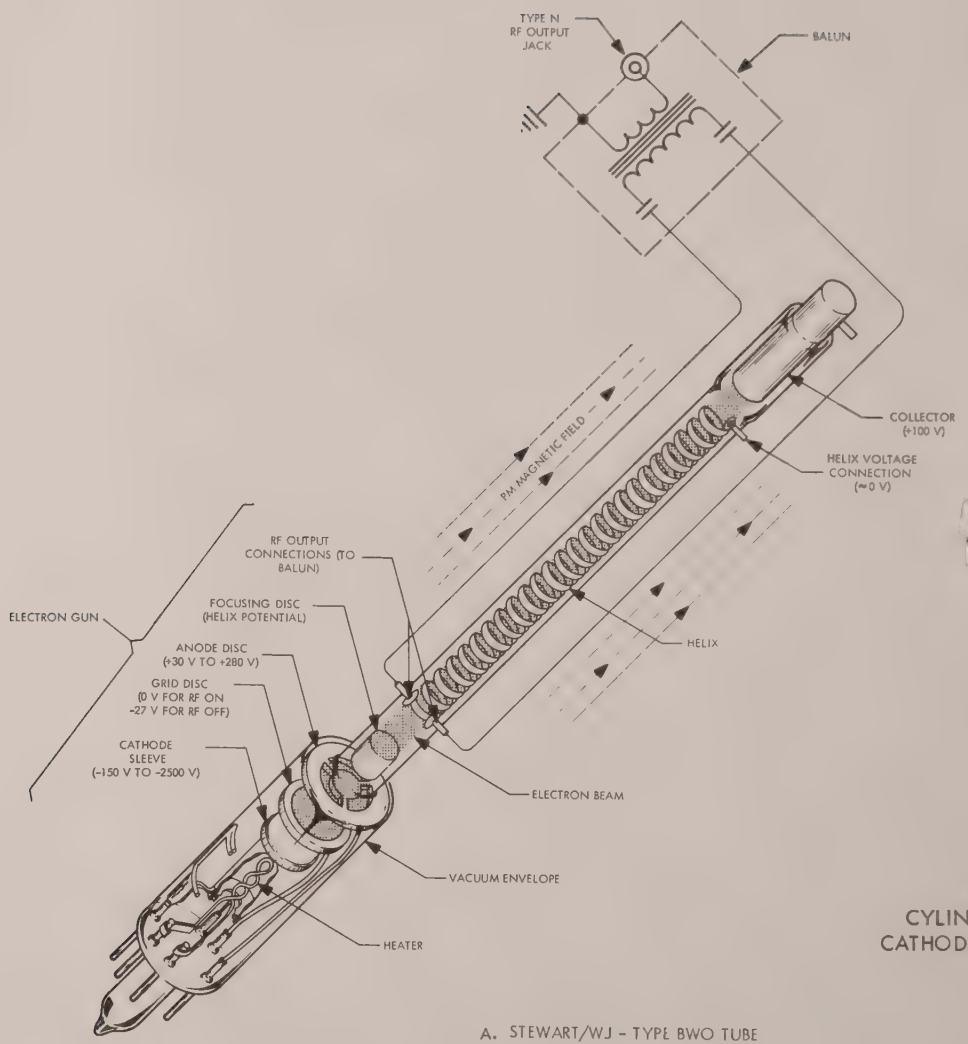
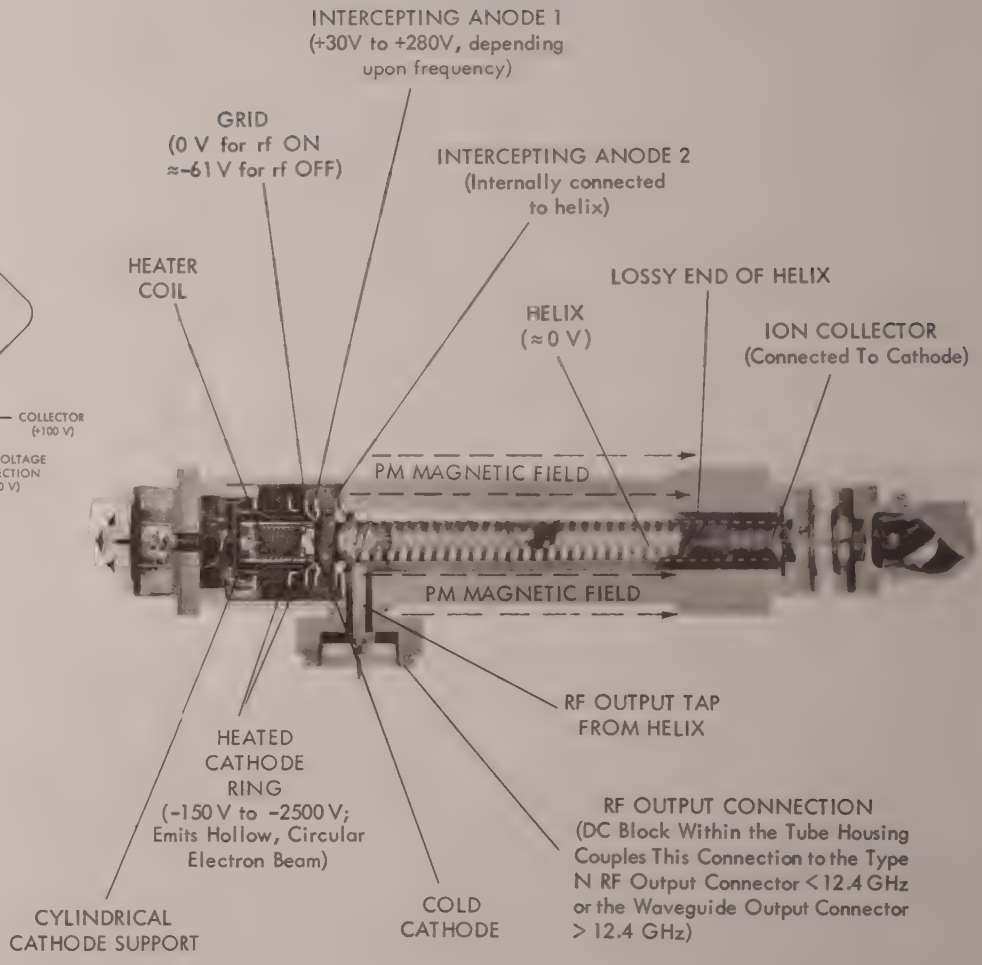


FIGURE 4-19. SIMPLIFIED DIAGRAM OF RF OUTPUT AND LEVEL CONTROL CIRCUITS

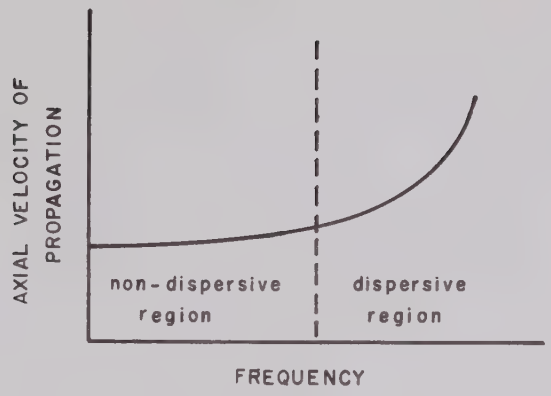

TYPE N RF OUTPUT JACK
BALUN
COLLECTOR (+100 V)
HELIX VOLTAGE CONNECTION (≈0 V)
PM MAGNETIC FIELD
RF OUTPUT CONNECTIONS (TO BALUN)
FOCUSING DISC (HELIX POTENTIAL)
ELECTRON GUN
ANODE DISC (+30 V TO +280 V)
GRID DISC (0 V FOR RF ON -27 V FOR RF OFF)
CATHODE SLEEVE (-150 V TO -2500 V)
HELIX
ELECTRON BEAM
VACUUM ENVELOPE
HEATER

A. STEWART/WJ - TYPE BWO TUBE


INTERCEPTING ANODE 1 (+30V to +280V, depending upon frequency)
GRID (0 V for rf ON ≈-61 V for rf OFF)
INTERCEPTING ANODE 2 (Internally connected to helix)
HEATER COIL
LOSSY END OF HELIX
HELIX (≈0 V)
ION COLLECTOR (Connected To Cathode)
PM MAGNETIC FIELD
PM MAGNETIC FIELD
RF OUTPUT TAP FROM HELIX
HEATED CATHODE RING (-150 V to -2500 V; Emits Hollow, Circular Electron Beam)
RF OUTPUT CONNECTION (DC Block Within the Tube Housing Couples This Connection to the Type N RF Output Connector < 12.4 GHz or the Waveguide Output Connector > 12.4 GHz)
CYLINDRICAL CATHODE SUPPORT
COLD CATHODE

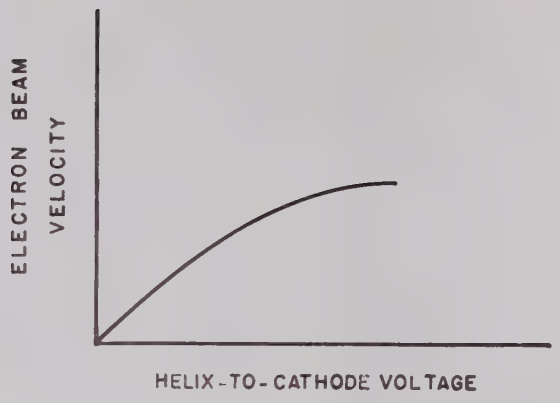
B. VARIAN-TYPE BWO TUBE

FIGURE 4-20. BACKWARD WAVE OSCILLATOR TUBE



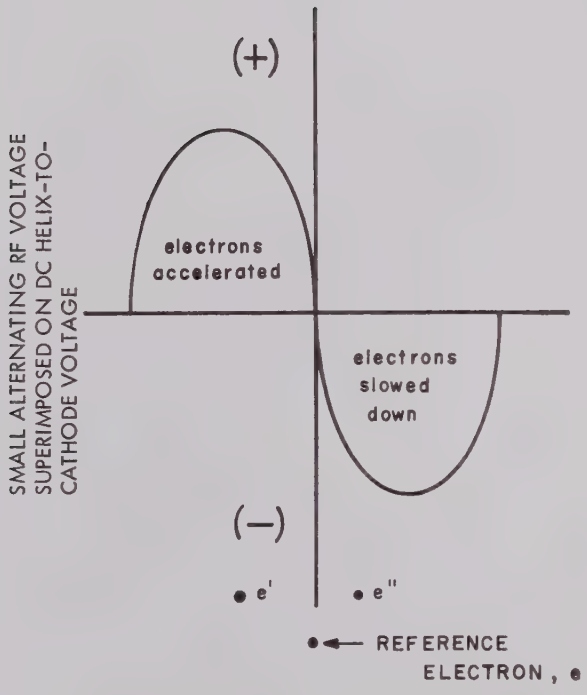
AXIAL VELOCITY OF PROPAGATION VS. FREQUENCY

(A)



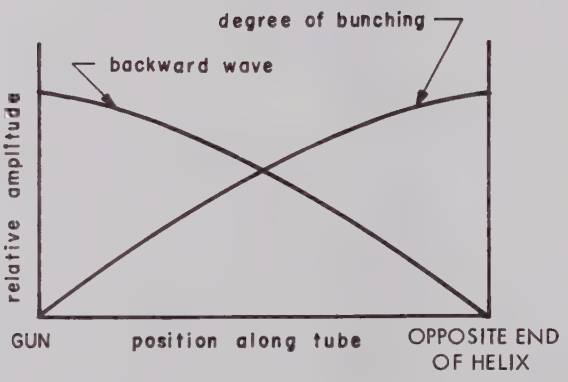
ELECTRON BEAM VELOCITY VS. HELIX-TO-CATHODE VOLTAGE

(B)



ELECTRON DISTRIBUTION

(C)



RELATIVE AMPLITUDE VS. POSITION ALONG TUBE

(D)

FIGURE 4-21. OPERATING CHARACTERISTICS OF BWO TUBE

sive region and it will oscillate at the frequency for which the electron beam velocity is very nearly equal to the axial velocity of propagation of the microwave signal on the helix. Figure 4-21A shows the variation of propagation velocity with frequency for a particular helix while Figure 4-21B shows how the beam velocity varies with the helix-to-cathode voltage.

From these figures it can be seen why the backward wave oscillator can be voltage tuned. By changing the helix-to-cathode voltage, the electron beam velocity changes, thereby changing the frequency for which the velocity of propagation on the helix and the velocity of the beam are in synchronism. The helix dimensions, primarily diameter and pitch, are chosen so that the tuning voltages required for a particular frequency range are reasonable (usually about 200 to 2000 volts).

The oscillations, and hence the rf wave, begin in the backward wave oscillator in much the same manner as they begin in other oscillators. Noise waves are established on the helix from the shot noise coupled from the electron beam and from thermal energy developed at the input end of the tube. Rf waves are produced which travel in both directions in the helix i.e., from gun to collector and from collector to gun. Since the desired wave in a backward wave oscillator must travel from the collector to the gun end, attenuators are placed in the tube which eliminate the forward-moving waves. Amplification of the rf wave is produced by the interaction of the electrons in the beam and the electromagnetic field of the wave.

To obtain this interaction, the electron beam must be at some critical velocity which is achieved by applying a dc voltage to the helix. Because the rf electromagnetic field is alternating, electrons in the beam are subjected to either an accelerating or decelerating field. Thus, the beam electrons passing axially near the helix experience velocity modulation, with a tendency for bunches of electrons to be formed as the beam moves through the helix. The critical areas of interaction are adjacent to the spaces between the helix turns because the axial electric field is strong between helix turns and weak under the turns.

To explain the bunching process let us examine a group of electrons as they travel from the gun to the opposite end of the tube. Within this group there will be one electron, e, which corresponds to the zero point of the alternating axial field and is therefore unaffected by the signal on the helix. See Figure 4-21C. This electron experiences no acceleration from the electromagnetic field. However, electron e', just to the left of e, encounters a positive axial field and is accelerated, thus tending to catch up with e. Similarly, electron e", which is just to the right of e, encounters a negative or decelerating field and so slows down and tends to be overtaken by electron e.

The electrons centered about e are thus velocity modulated. This situation is repeated over and over again as the electrons centered about the reference electron pass one space after another enroute from the gun to the lossy end of the helix.

If the helix-to-cathode voltage is set to achieve a beam velocity such that at the collector end of the tube the phase difference between the wave and bunches in the beam is approximately one half cycle, the electron bunches will encounter relatively strong decelerating fields as they cross the spaces. Thus, the kinetic energy of the electrons is transferred to the backward wave. The amplitude of the backward wave builds up as it progresses toward the gun end of the tube because it passes more and more bunches from which it receives energy.

At the same time, the alternating component of the beam current, i.e., the bunching, becomes greater as the electrons progress through the tube, because of the continuing velocity-modulation interaction between the beam and the established backward wave. See Figure 4-21D.

In the Stewart tube, the rf output signal generated on the helix is coupled off the helix at the gun end on two insulated wires which terminate in an external balun. The balun contains capacitors which block the dc operating potential and allow the output type N connector to operate at chassis ground. These two wires are connected to the end loop of the helix at points 180° apart, to provide balanced output.

In the Varian tube, the rf output signal generated on the helix is coupled off through a dc-blocking capacitor at the gun end, and drives a properly-matched type N or waveguide output connection which operates at chassis ground.

The required cathode-to-helix operating potential is obtained by operating the helix near chassis ground and the cathode below ground. To shift the operating frequency from the low to high band limits, an exponential change of cathode supply voltage over a range of about 7:1 is required. The diode shaper board A13 is factory-set to provide the proper tuning voltage range for each tube, within the supply limits of -150 V to -2500 V.

The anode is operated at a positive potential with respect to the cathode, and the elevated supply board A12 is factory-set to provide feedback that develops the required output within the supply limits of +30 V to +280 V. The grid is operated at cathode potential for full rf output power, and at -27 V (Stewart tubes) or -61 V (Varian tubes) to cut off the electron beam, thereby turning off the rf output completely. This grid control is used for on-off modulation.

Typical cathode current is less than 30 milliamperes, and in Stewart tubes it divides between the helix and collector. In Varian tubes, it divides between the anode and helix, and all beam current not intercepted by the anode flows through the helix lead. In Stewart tubes, the collector is operated at above-ground potential through a resistor from the +100 V supply, and thus is 100 V positive with respect to the helix.

Helix, collector and anode operating currents are critical operating parameters and must not exceed the power dissipating capability of the tube elements. Proper operating current for these electrodes on the particular tube installed in each plug-in unit are indicated on Addendum A enclosed in the envelope bound into the rear of this manual. Because of variations in optimum operating currents and distribution of currents between electrodes in BWO tubes of the same type, the rf power output characteristics should be used as the principal indicator of tube performance.

The rf power output is proportional to the beam current. Beam current is controlled by both grid bias and anode voltage, and maximum beam current is limited by the power dissipating capacity of the helix and anode. Since variations in anode voltage also affect the frequency of oscillation, the sweep oscillator operates with constant anode voltage, and grid bias is used for on-off control of power output. The use of PIN diode leveling for analog power control eliminates the slight frequency-pulling effect that is obtained by use of grid modulation to vary the output level. The use of grid control for on-off control does not cause frequency pulling since the output is cut completely "off" whenever such grid voltage is applied.

In the "standby" mode when the FREQUENCY Mode Selector switch is turned OFF, the heater, cathode, anode, collector, and helix voltages are maintained, and the grid is biased to cut off the beam. With the other voltages applied, the tube is continuously being outgassed, and it has been found that through this technique, tube life is extended by more than 10%.

4.20 BWO TUBE PERFORMANCE MONITORING. Cathode, heater, and anode supply voltages are monitored by means of TP6 through TP9 on the top of the chassis, which connect to the supply outputs. Grid voltage, which is developed in the active stage of the elevated supply PC Board A12, is monitored by A12TP3 on the elevated supply, at the top rear of the instrument.

Helix current is coupled to terminal 19 of the elevated supply, through the normally-closed contact of FREQ STABILIZING INPUT connector J39. In units having Stewart tubes, this current is shunted to ground through A12R2, a factory selected resistor (nominal value 12.5 - 20 ohms) in the elevated supply in paralled with A7R10, a 49.9-ohm resistor in the helix overcurrent protection circuit (see Figure 4-10). The helix current divides between the two resistors in a suitable ratio, so that a total of between 3.5 and 5 ma helix current, depending upon the tube, is required to produce 1 ma across A7R10 which trips the helix overcurrent relay. The voltage produced by the helix current flow through these resistors and through series resistor A12R15 is monitored at A12TP2. The monitored voltage will be 100 mv/helix ma, and will be less than 350-500 mv, which corresponds to the tripout level. In units having Varian tubes, the helix current is shunted to ground through A12R2 in the elevated supply, in parallel with A7R10, a 49.9-ohm resistor in the helix overcurrent protection circuit (see Figure 4-10). A12R2 is a factory-selected resistor with a nominal value of 1.5-5 ohms. The helix current thus divides between the two resistors, so that a total of between 11 and 34 ma helix current, depending upon the tube, is required to produce sufficient current (about 1 ma) across A7R10 to trip the helix overcurrent relay, which also removes the anode voltage. The voltage produced by the helix current flow through these resistors and through series resistor A12R15 is monitored at A12TP2. The series resistor is also factory-selected, so that the monitored voltage will be 10 mv/helix ma.

Collector current is coupled to the +100 V supply through a 10-ohm resistor. A12TP1 is tied directly to the collector, so that the voltage developed by the collector current passing through the resistor will cause the voltage at A12TP1 to drop from +100 V (TP-1) by 10 mv/collector ma.

The +100 V supply input to the elevated supply is not used with Varian tubes. A12TP1 is non-functional in units with Varian tubes.

4.21 FREQUENCY STABILIZING INPUT.

The FREQUENCY STABILIZING INPUT jack J39 provides a means of applying feedback to the helix to alter the instantaneous helix-to-cathode voltage in single-frequency operation. When generated by a suitable discriminator, such feedback can stabilize the rf single-frequency output to an accuracy approaching that of the best cavity-tuned microwave oscillators. When a mating connector is inserted in J39, it opens the normally-closed contacts shunting R86, so that the applied stabilizing feedback voltage is developed across R86, in series with the helix-to-ground voltage produced by the helix current flow through A12R2 and A7R10. When external stabilization is used, the discriminator voltage applied across R86 ranges between 0 and ±50 V. A positive voltage tends to increase the axial velocity of propagation of the electron beam by increasing the voltage differential between the cathode and helix. This tends to increase the oscillation frequency, in accordance with Figure 4-21A. Conversely, a negative voltage tends to decrease the beam velocity and output frequency. The response characteristics are mainly determined by the external feedback discriminator used to generate the stabilizing signal. The discriminator must have a low output impedance in order to supply the required helix current without affecting the voltage stabilization action.

4.22 DIODE SHAPER BOARD (see Figure 4-22).

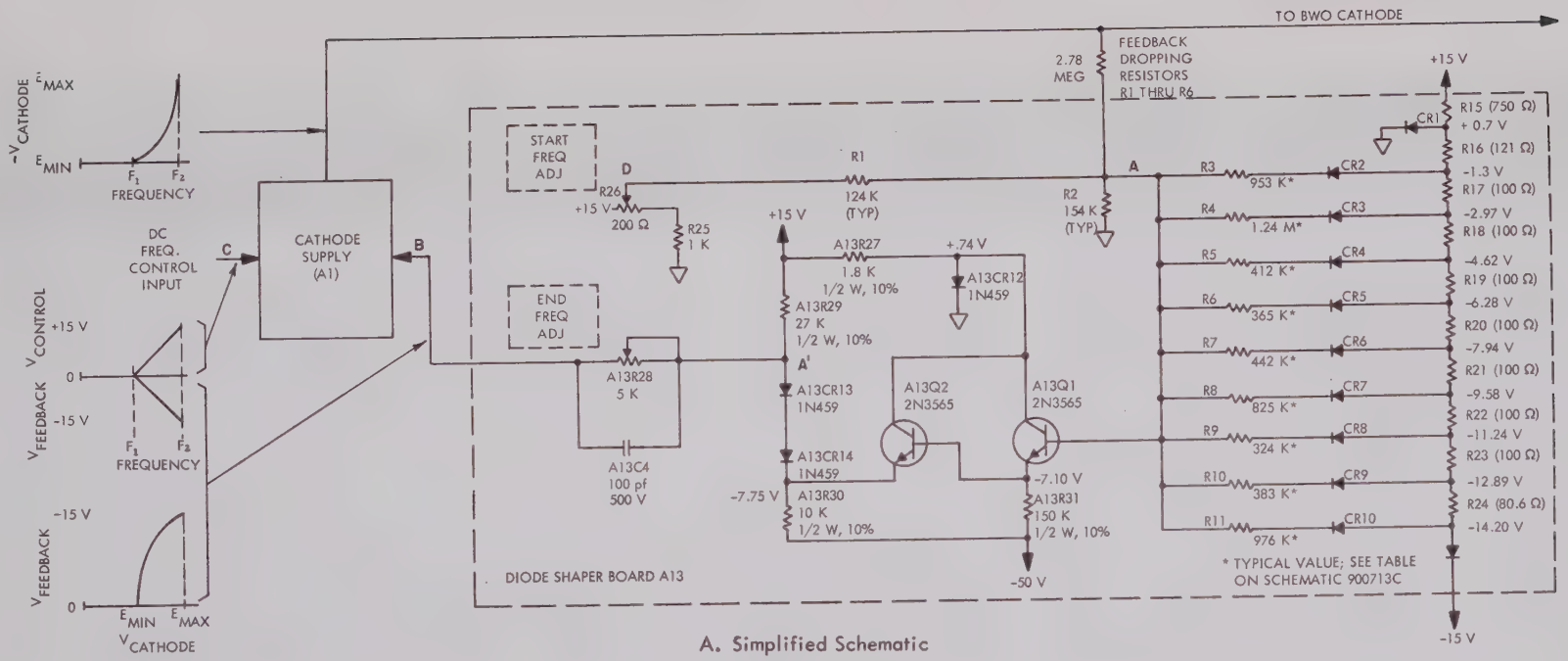
The diode shaper board A13 provides non-linear feedback as required to produce a tube electron beam velocity which yields frequency output that is linear with sweep time or control voltage. The non-linear relationship of frequency to propagation velocity or electron beam velocity, and the resultant requirement for non-linear helix-to-cathode voltage is evident from Figure 4-21A and B. Since the control voltage is linear with sweep time or sweep frequency, the cancelling feedback must be developed in non-linear fashion, so that a non-linear cathode voltage-vs-frequency curve will result when the feedback is used to balance out a linear control voltage.

The diode shaper board provides this non-linear feedback by shunting away an increasing portion of the feedback current through a biased-diode ladder shunt network as the output level increases. This network is biased by a resistor string connected between + and -15 V, such that only one diode is conducting at the lowest supply voltage, and all diodes are conducting at the highest supply voltage, with a non-linear turn-on curve in between. Thus, an increase in the cathode supply voltage produces a feedback voltage increase at a slower rate (negative slope derivative) as shown in Figure 4-22B. Since the cathode supply circuit increases its voltage output until the control and feedback signals applied to its summing junction cancel, this means that a linear increase in control voltage drives the cathode supply output in non-linear fashion with a positive slope derivative, as shown in Figure 4-22C, to produce feedback cancellation.

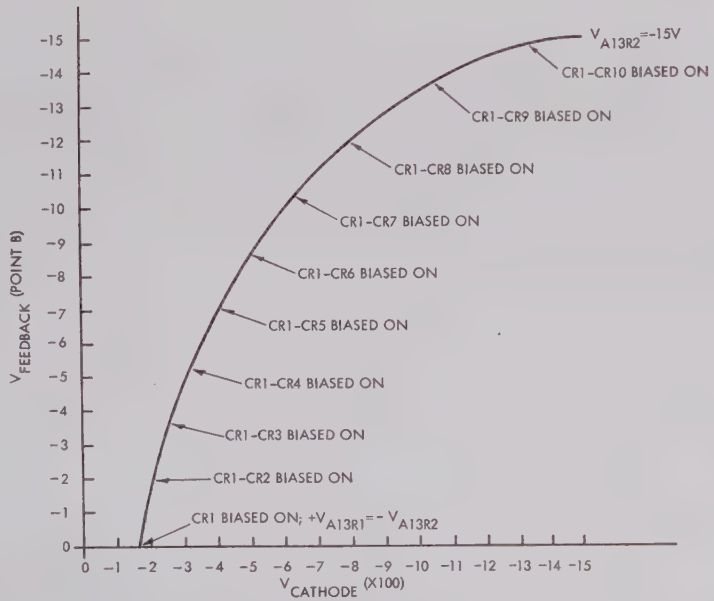
The resultant cathode supply voltage vs. frequency curve produces a linear frequency vs. control voltage performance curve. Mathematically, the curve of required cathode supply voltage vs. frequency (Figure 4-22C) approximates a third-order exponential function. By establishing a feedback curve that corresponds to the second derivative of that curve, a linear feedback voltage-vs.-frequency curve is obtained at point B, since the second derivative of a third-order function is linear.

The feedback current supplied to the low-voltage diode shaper board at point A, after passing through dropping resistors R80 through R85, is a fixed fraction of the negative cathode supply output. The feedback voltage developed between point A and ground is produced by the feedback current through A13R2. The ladder network, composed of diodes A13CR1 through A13-CR10 and resistors A13R1 through A13R11, achieves the feedback slope shown in Figure 4-22B by progressively shunting a greater percent of feedback current away from A13R2 as the feedback level exceeds the "turn-on" voltage of each biased diode.

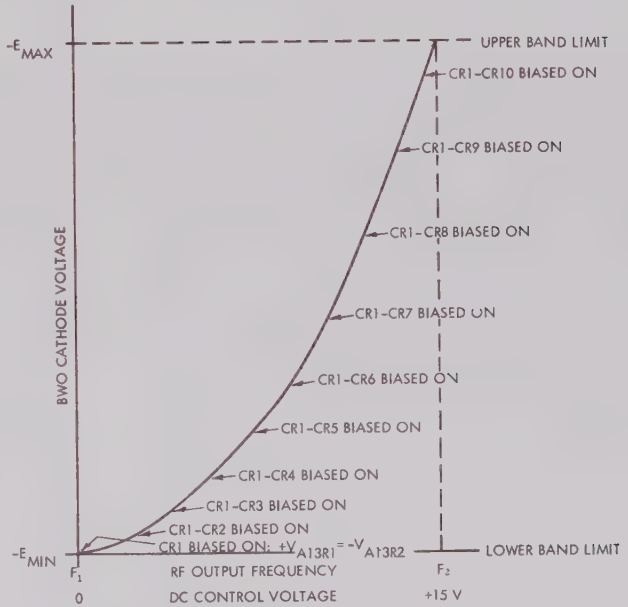
Amplifier stages A13Q1 and A13Q2 are emitter-follower stages that serve as an impedance converter amplifier to provide a low-impedance output at point B with the same voltage as the feedback level at point A. The point B output then serves as a suit-



A. Simplified Schematic



B. Typical Diode Shaper Feedback Characteristic



C. Typical Overall Voltage vs. Frequency Characteristic for the Feedback-Controlled Cathode Supply

FIGURE 4-22. SIMPLIFIED SCHEMATIC AND OPERATING CHARACTERISTICS OF DIODE SHAPER BOARD

able low-impedance source for summing junction feedback current through summing resistors A1R6 and A1R38 in the cathode supply.

Resistors A13R15 through A13R24 and diode A13CR11 establish the bias on the diode string, and are the same value in all shaper boards. Diode A13CR1 stabilizes the voltage at the junction of A13R15 and A13R16 as the current load changes during feedback shunting conditions. Resistor A13R1 through A13R11 are different for each plug-in unit model, and are selected to obtain the desired curve by shunting away a greater percent of the increasing feedback current as the feedback voltage level reaches the forward-biasing point for each diode. The overall effect is that the feedback voltage developed at point A rises as cathode voltage increases, but at a slower rate, because resistors A13R3 through A13R11 shunt away part of the current that would otherwise pass through A13R2 to develop feedback voltage between point A and ground.

The resultant feedback voltage curve (Figure 4-22B) is a smooth-curve approximation with nine (9) gradual slope changes as the feedback level reaches the turn-on points of A13CR2 through A13CR10. The decrease in slope at each turn-on point is related to the additional shunting effect of the individual resistance values of A13R3 through A13R11 and the net difference between the level at point A and the return voltage of each diode.

At the low band-edge output frequency, the cathode supply output voltage must have a negative value corresponding to the minimum bias requirement of the tube, while the control voltage is zero. Thus, a zero feedback voltage must be developed at a finite supply output level, as shown by the X-axis intercept of the curve in Figure 4-22B. This is accomplished by selecting the value of A13R1 and setting its return voltage (point D) at a positive level between 12.5 and 15 V by means of Start Frequency Adjust resistor A13R26. This positive offset circuit then biases point A positively until the cathode supply voltage increases to the point where the cathode supply feedback voltage supplied to point A equals the positive offset voltage. This establishes a 0-volt null at point A, as required for zero feedback voltage. As the control voltage is subsequently increased above 0 to +15 V, the feedback developed at point A increases non-linearly from 0 to -15 V.

The dc impedance converter amplifier (A13Q1 and A13Q2) consists of two cascaded emitter follower stages with the collectors held close to ground level by A13CR12. Diodes A13CR13 and A13CR14 compensate for the sum of the emitter-base drops in A13Q1 and A13Q2 when these transistors are biased to heavy conduction by a 0-level feedback signal at point A, thus developing a 0-level signal at point A'. As the feedback signal increases to the -15 V level, the conduction of A13Q1 and A13Q2 decreases so that the voltage at A' tracks that at point A, but has a higher source impedance to drive the summing junction.

The End Frequency Adjust resistor A13R28 provides an adjustment for the feedback current supplied from the diode shaper board to summing resistor A1R6 in the cathode supply. It can be used to adjust the overall slope of the diode shaper board curve by establishing the feedback level required to generate 1 ma feedback current to the summing junction at the upper band limit. This then sets the maximum cathode supply voltage limit corresponding to that required by the BWO tube for the upper band-limiting frequency. When the BWO tube is replaced, adjustment of A13R1 and A13R28 permits the feedback of the diode shaper board to be tailored to the characteristic of the new tube without requiring replacement of fixed resistors on the diode shaper board.

4.23 LEVELING OPERATION IN GRID-LEVELED UNITS (Models 64(*)0, 64(*)1, and 64(*)4 Only).

4.23.1 GENERAL (See Figure 4-23 and Schematics 900872 and 900845). The leveler-amplifier (A11) operates as a closed-loop differential error signal amplifier driving the grid of the BWO tube (via the transfer oscillator) to correct for differences between the control and sampler signal levels applied to the differential input stage through A11-B and A11-C. The leveler amplifier consists of a differential amplifier stage (A11Q1) followed by two emitter-follower stages (A11Q2 and A11Q3). There is also a single-stage amplifier (A11Q4) which drives the UNLEVELED WHEN LIT lamp.

With RF OUTPUT switch $A11_1$ S1 in the LEVELED mode, the leveler amplifier receives an input signal through terminal A11-B from the rf sampler crystal detector, to drive one side of A11Q1. On units with an internal sampler, RF SAMPLER switch S18 selects either the internal or external sampler to drive the leveler amplifier. The rf sampler signal has an amplitude of at least -60 mv at a level corresponding to the maximum power available with full-band leveling.

The signal from the leveler reference output of the modulator is tapped from the POWER LEVEL control resistor $A11_1$R3 and applied through A11-C to the other side of dual transistor A11-Q1. The signal level at $A11_1$R3 has a maximum amplitude of -300 mv corresponding to unmodulated output, and an amplitude of 0 V corresponding to "full off" modulation. With unmodulated output, the POWER LEVEL control $A11_1$R3 adjusts the level applied to A11-C between 300 mv and a minimum level set by the Minimum Power Limit control $A11_1$R4, which is connected between $A11_1$R3 and ground. Adjustment of $A11_1$R4 sets the minimum level of the output provided by $A11_1$R3 between -60 mv and 0 mv.

The nominal minimum setting of about -20 mv corresponds to a square-law sampler output level 5 db below the nominal -60 mv which corresponds to the full-band-leveled power point. The maximum setting of -300 mv corresponds to sampler output of up to 7 db above the full-band-leveling point, to permit partial-band leveling at higher power levels in accordance with the tube characteristic.

4.23.2 LEVELER-AMPLIFIER OPERATION. If the level applied to A11-C is more negative than that supplied to A11-B, a condition of "insufficient rf output power" is indicated. In that case the relatively greater forward bias on the left half of A11Q1 causes it to conduct more heavily and take control of the differential stage. The result is that the base of A11Q2 is driven close to +15 V, reducing its conduction. The reduced conduction of A11Q2 isolates the base of A11Q3 from +15 V, thereby dropping the applied base voltage at that transistor and reducing its conduction. The result is a drop in the positive output signal supplied to the transfer oscillator through A11-E. This reduced control signal reduces the amplitude of the grid driver output from the transfer oscillator. The reduced-amplitude driver output reduces the negative bias applied to the grid by the active modulator stage A12Q1 in the elevated supply, thereby increasing the rf power output from the BWO tube.

If the level applied to A11-B is more negative than that applied to A11-C, indicating "excessive output power," the amplifier stages respond in an opposite manner to increase

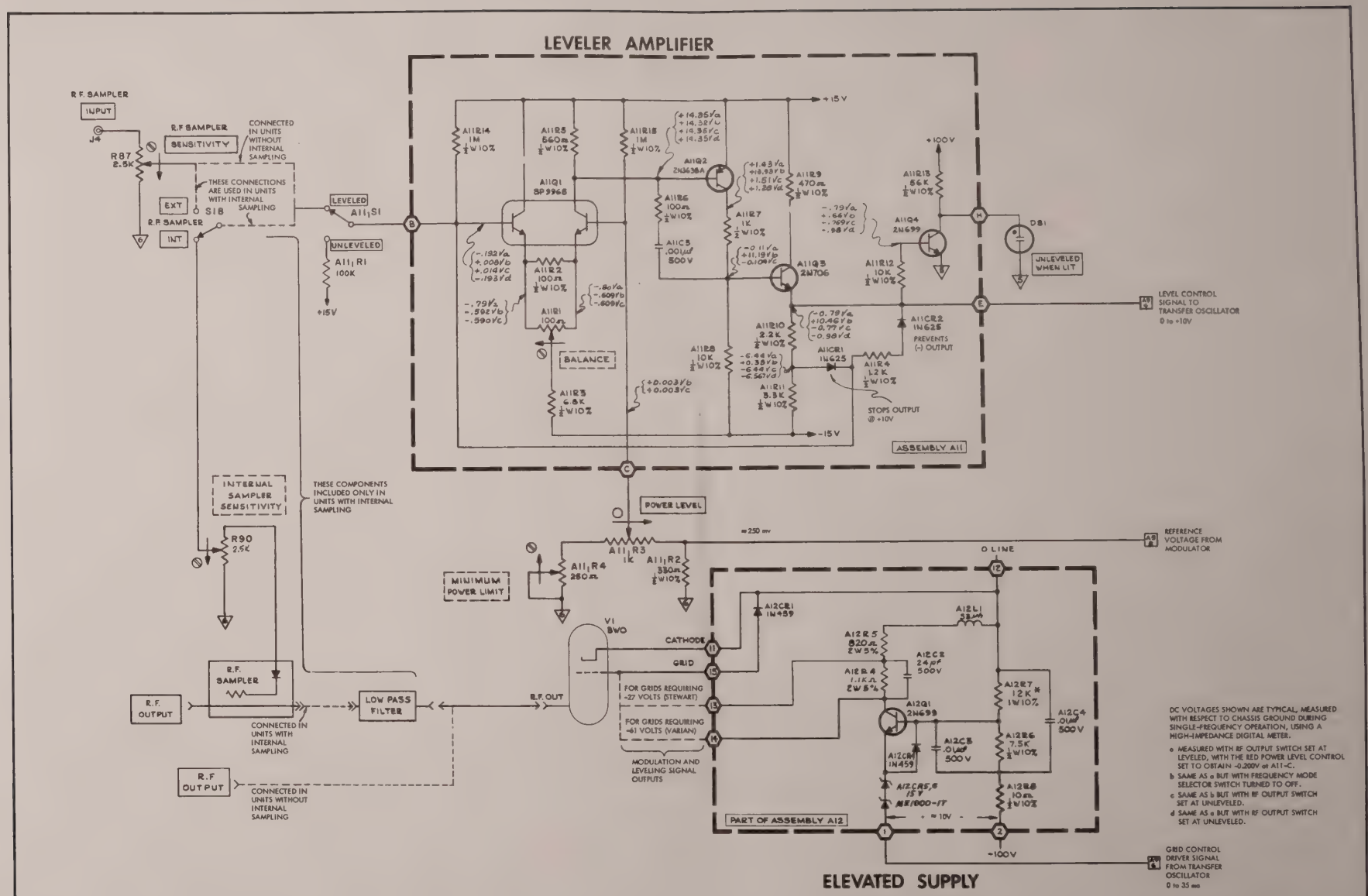


FIGURE 4-23

SIMPLIFIED SCHEMATIC OF [redacted] GRID LEVELING CIRCUITS

the conduction of A11Q3 and thereby increase the positive output signal supplied to the modulator through A11-E. This increases the drive signal output of the transfer oscillator to increase the negative grid bias developed by A12Q1 in the elevated supply, thereby reducing the rf power output from the BWO tube.

In the LEVELED position of $A11_1$ S1, the input to A11-B is obtained from either an external or internal sampler (as applicable), to provide the closed-loop level control operation described above. In the UNLEVELED position of $A11_1$ S1, A11-B is connected to the +15 V supply through 100 K resistor $A11_1$-R1. This assures that the base of the left half of Q2 is biased more positively than the base of the right half, a condition equivalent to the "insufficient output power" condition in the leveled mode. As a result, regardless of the setting of POWER LEVEL control $A11_1$R3, the right half of A11Q1 conducts only slightly, and A11Q3 is thereby biased to minimum conduction so that the output signal supplied to the modulator through A11-E is at 0 V.

Amplifier response is stabilized by a feedback loop consisting of A11C3 and A11R6 around the A11Q2 stage. Diode A11CR1 establishes a negative feedback path between the emitter-follower output resistor string in the A11Q3 stage and the base of the left half of A11Q1. This feedback limits the drop across A11R11 and prevents the output at terminal E from going more positive than +11V, thereby avoiding saturation of both the leveler and transfer oscillator. The A11CR1 feedback loop stabilizes leveler response when square-wave modulation is used by smoothing the delay interval between the modulator reference signal amplitude change at A11-C and the subsequent sampler signal change at A11-B. It permits the leveler to maintain control of the "power on" signal envelope without interfering with individual cycles of the square-wave modulation.

This feedback does not significantly degrade the leveling performance for the modulated signal envelope or for unmodulated CW signals, since level variations in such signals occur at a rate at least an order-of-magnitude slower than the rise and fall time of the square-wave modulation.

Diode A11CR2 prevents the output from going more negative than -1V, since the transfer oscillator Diode A11CR2 works only with positive signals. The leveler amplifier frequency response is set by the R-C bypass network A11C3-A11R6. This network prevents leveler oscillation by controlling the high-frequency gain and phase response.

4.23.3 UNLEVELED LIGHT OPERATION. Transistor A11Q4 controls the UNLEVELED WHEN LIT lamp $A11_1$ DS1. This lamp is lit when +100 V is applied to it through A11R13. When $A11_1$S1 is in the UNLEVELED position, the output signal developed at A11-E is 0 V, as described above. In this case A11Q4 is held cut off, and $A11_1$ DS1 is lighted. When the output signal at A11-E is continuously above 0 V, indicating that controlled leveling performance is taking place throughout the range being swept, the positive signal biases A11Q4 to conduction. A11-Q4 then couples A11-H to ground and extinguishes $A11_1$ DS1. If leveled performance is obtained over just a fraction of the range being swept, A11Q4 is turned on and off, and the capacitance of $A11_1$ DS1 stabilizes the voltage of A11-H at a level that keeps $A11_1$ DS1 lit.

4.24 LEVELING OPERATION IN PIN DIODE-LEVELED UNITS (Models 64(*)2, 64(*)3, and 64(*)5 Only).

4.24.1 GENERAL (See Figure 4-19). The leveler-amplifier (A11) operates as a closed-loop differential error signal amplifier, driving the PIN diode attenuator assembly to correct for differences between the control (reference) and sampler (crystal detector) signal levels applied to the differential input stage through A11-6 and A11-7. The output signal is applied to the PIN diode attenuator driver from A11-15, to control both the leveling and matching diodes.

Whenever the reference and crystal detector signals do not cancel, the differential input stage of the main leveling loop in the leveler-amplifier generates a correction signal, ϵ_1, which is amplified by A_1 in the main leveling loop and applied to the A_2 stage. The gain equalizing loop compensates for variations in PIN attenuator and crystal detector sensitivities as power level changes, to maintain a constant voltage gain from ϵ_2 to e_s. This provides optimum response at any operating power level. The output from A_2, applied through the PIN diode attenuator circuits, controls the PIN attenuator to supply the necessary level-correcting output attenuation, and also controls the matching diodes to balance the instantaneous resistance of the leveling diodes so that the PIN attenuator rf network yields a fixed 50-ohm input and output impedance.

The sensitivity of the feedback-stabilized leveler-amplifier is high enough that it levels the rf output to within a fraction of a db regardless of the unleveled characteristic of the tube. As the output sweeps through frequencies where the unleveled characteristic is several db higher than the minimum-power point in the band, the leveler increases the correction signal in response to the increased crystal output, and prevents the level from increasing more than about 0.3 db.

Whenever power is leveled over the full range being swept, a negative signal is continually supplied from the PIN diode attenuator driver to a two-stage amplifier to cut off power from the UNLEVELED WHEN LIT light. The absence of a suitable driver output signal during any portion of the swept band, indicating that the rf output signal is totally or partially unleveled, is sufficient to allow this amplifier to energize the UNLEVELED light.

The signal level applied to the leveler-amplifier from the internal or external detectors is adjustable with individual SENSITIVITY controls to provide optimum response in the leveled loop.

For control of output level in the unleveled mode, the leveler-amplifier drives the PIN attenuator to provide a fixed output attenuation with a magnitude controlled by the setting of the POWER LEVEL control. The crystal detector signal to the differential input for A_1 is grounded, and the main leveling loop consisting of A_1 and A_2 acts as a single-ended amplifier for the level-control signal supplied by the POWER LEVEL control. The reference signal supplied to the POWER LEVEL control in this mode is developed by a voltage divider from the -15 V supply. The feedback signal for the unleveled mode is developed by the A11Q10 amplifier stage which samples the voltage supplied to A_2. This feedback permits closed-loop operation of the leveler-amplifier to provide the proper leveling control voltage (and therefore output attenuation) in response to any setting of the POWER LEVEL control.

The main leveling loop consists of A11Q1-Q5, A11Q7-Q9, and A11Q11. A11Q1 serves as a differential summing junction, and receives the reference voltage, e_r, from the POWER LEVEL control, and the rf sampler detector output signal, e_s.

It develops an error output signal, ϵ_1, which is amplified by differential stage A11Q3/Q4 and single-ended stage A11Q5. The output, e_1, from A11Q5 is combined with e_2 at A11Q7/Q8, which serves as another differential summing junction. The final error signal, ϵ_2, developed by A11Q7/Q8 is amplified by single-ended stage A11Q11 which supplies the control voltage to the leveler driver.

Within the self-balancing leveling system, the PIN diode attenuator can be thought of as a variable-gain attenuator which offers the greatest attenuation in response to the highest sample voltage and the least attenuation in response to the lowest sample voltage, thereby tending to maintain the power output constant at the desired level which corresponds to the POWER LEVEL control setting. The gain equalizing loop functions to improve the performance of the variable-gain leveler attenuator by attempting to hold the amplification from e_1 to e_s constant, regardless of the power level at which the error occurs. It thereby compensates for the sampler crystal sensitivity variations and the natural gain-bandwidth variation of the amplifier in responding to error signals. Over the full-control range of the leveler (which is variable attenuation range >15 db), the gain equalizing loop attempts to maintain a constant effective gain from e_1 to e_s of -20 db, so that e_s tends to be 20 db below e_1 regardless of the absolute level of e_s.

4.24.2 OPERATION OF MAIN LEVELING LOOP AND GAIN-EQUALIZING LOOP IN LEVELED MODE (See Figure 4-19 and Schematic 900933).

Detailed operation of the main loop and gain-equalizing loop is as follows: If the rf output tends to increase to a greater level than that corresponding to the setting of the POWER LEVEL control, the (-) voltage applied to A11-7 from the sampler detector will exceed the reference level applied to A11-6. A11Q1 will become unbalanced, so that the conduction of its right-hand side will be diminished, and the left-hand side will tend to conduct heavily and take control of the stage. The heavier conduction through A11R1, compared with A11R2, will provide greater forward bias to A11Q4, compared to A11Q3, so that A11Q4 conducts more heavily and takes control of the A11Q3/Q4 differential stage. The output from this stage, obtained from the collector of A11Q3, goes negative due to the diminished conduction of A11Q3. This negative-going output tends to reduce the conduction of A11Q5, so that its single-ended output is positive-going. This positive-going signal is applied to the base of A11Q7.

This positive-going voltage change reduces the conduction of A11Q7, producing a negative-going change at the base of A11Q11. The conduction of A11Q11 is thereby increased, drawing more current through A11R37, to drop the leveler control voltage at A11-15. The PIN diode leveler increases its attenuation in response to a drop in control voltage, thus tending to correct for the increase in output power that produced the error signal. Conversely, if the rf output tends to decrease to a level below the setting of the POWER LEVEL control, error signal polarities will be reversed, and the conduction of A11Q11 will be reduced, so that the leveler control voltage becomes less negative, thereby reducing the attenuation. The control signal range at A11-15 is -2 V (maximum attenuation) to -0.5 V (minimum attenuation).

The control signal magnitude produced by the error signal applied to A11Q7 is altered by A11Q8, the other half of the differential stage, which is controlled by the gain equalizing loop amplifier. The negative-polarity sampler signal at A11-7 is applied to the left-hand base of A11Q6 in the gain equalizing amplifier, to provide this control. The sampler signal tends to reduce the conduction of that side of the differential stage by an amount proportional to its magnitude. Since the right-hand base of A11Q6 is connected to ground, this side will always conduct more heavily, but the amount of excess conduction will be proportional to the sampler signal level, i.e. a low-level sampler signal will allow both sides of A11Q6 to conduct almost equally, while a high-level signal will reduce the conduction of the left-hand side, so that the righthand side conducts more heavily. As conduction of A11Q6(R) increases, increased forward bias is applied to A11Q8, causing it to rob current from A11Q7. This reduces the error signal amplification of A11Q7 at high power levels where crystal sensitivity (in terms of Δ db/mv) is greater, and increases it at low power levels where crystal sensitivity is lower. Thus, the gain from e_1 to e_s tends to remain constant.

4.24.3 OPERATION OF PIN DIODE ATTENUATOR AND DRIVER CIRCUIT (See Figure 4-19).

The PIN diode attenuator consists of a pi-network of four shunt diodes and two series diodes connected to form a variable-attenuation transmission line with input and output matching at all attenuation levels. PIN diodes act as electically variable resistors at microwave frequencies, with resistance inversely related to forward bias current in a non-linear manner. Each diode can be varied in resistance over a range of about 10,000 ohms to less than 25 ohms as the applied dc bias current varies from reverse-bias conditions to a maximum forward bias of about 30 ma.

The overall attenuation of the attenuator module ranges from a minimum of ≈ 5 db (max. insertion loss of the structure with the series diodes biased "on" and the shunt diodes biased "off") to a maximum of ≈ 33 db (max. attenuation with the series diodes biased "off" and the shunt diodes biased "on"). In operation the attenuation is controlled over this range by individual signals supplied to each series and shunt diode by the leveler driver circuit, in response to the single control signal developed at A11-15. Thus, a control signal ranging from -0.5 V to -2.0 V from A11 provides full attenuation control from minimum to maximum, respectively.

The attenuator driver circuit and PIN attenuator are factory-adjusted to operate as a single, non-repairable module. The driver circuit includes a control function shaping circuit and separate, factory-adjusted current driver amplifiers for each series and shunt diode. The module has ample design margins in each circuit to assure long life and trouble-free performance. No re-adjustment should be required for the life of the module.

4.24.4 OPERATION IN UNLEVELED MODE (See Figure 4-19).

In the leveled mode, the leveler circuits operate as a closed loop rf level control system with rf sensing and feedback. In the unleveled mode, the system operates as an open-loop rf level control system, and electronic feedback is developed within A11 to close the control signal loop without rf sensing. In the unleveled mode, $A11_2S2(C)$ grounds the sampler signal input so that e_s is zero. This disables the gain equalizing loop and converts the main leveling loop to single-ended rather than differential amplifier operation. To permit accurate adjustment of the power level of the unleveled signal using the POWER LEVEL control $A11_2R6$, amplifier A11Q10 develops a negative feedback signal proportional to the control signal amplitude. This feedback current, combined with the POWER LEVEL control signal current at A11-6, reduces the open-loop gain of the

main leveling loop and causes it to operate as a stable dc operational amplifier having gain set by the ratio of A11R31 to A11$_2$R5 (6.67:1). (A11Q10 and A11Q11 are unity-gain emitter followers which provide output isolation and low impedance drive for the feedback and attenuator control outputs.)

In the unleveled mode A11$_2$R6 is driven by a -275 mv signal developed by A11$_2$R3 and A11$_2$R2 from the -15 V supply. The leveler amplifier, operating as a dc operational amplifier, converts the ≈30-275 mv output range of the POWER LEVEL pot A11$_2$R6 into a -2.1 V to -0.4 V attenuator control range, to provide control from maximum to minimum attenuation respectively.

4.24.5 DEVELOPMENT OF REFERENCE LEVEL INPUT SUPPLIED TO A11-6 (See Figure 4-19 and Schematics 907055 and 900933).

4.24.5.1 Leveled Operating Mode. The reference level supplied to A11-6 in the leveled operating mode is the sum of the control signal tapped from the POWER LEVEL potentiometer, A11$_2$R6, and the control voltage "maximum limit" feedback signal developed at A11-17 through A11CR2. Within PC board A11, there is another feedback loop consisting of A11CR1 which supplies the control voltage "minimum limit" feedback signal to the common junction of A11-6 and the left-hand base of A11Q1.

In the leveled mode, the POWER LEVEL pot is driven by the leveler reference output from the modulator (A5-R via P6-8). This signal has a maximum amplitude of about -300 mv corresponding to unmodulated output, and an amplitude of 0 V corresponding to "full off" modulation. Thus, during square-wave or other "on-off" modulation, the leveler reference signal at A11-6 is reduced to 0 V at the same time the rf output drops to 0 (which causes the sampler input at A11-7 to drop to 0), so that the leveler can remain in balance rather than being driven to saturation. With unmodulated output, the variable level applied to A11-6 by adjusting the POWER LEVEL control A11$_2$R6 ranges between 300 mv and a minimum level set by A11R5, which is connected between A11$_2$R6 and ground. Adjustment of A11R5 sets the minimum level of the output provided by A11$_2$R6 between -60 mv and 0 mv, and the normal setting is selected to provide a power control range of 10 db below the power level at which full-band leveling occurs.

The voltages at A11-6 and A11-7 are near zero during the "rf off" time for retrace between sweeps or square wave modulation. In this condition the difference in values of A11R1, and A11R2 causes the A11-15 quiescent control voltage to go negative. The control voltage "maximum limit" feedback applied to A11-6 through A11-17 keeps the A11-15 control voltage from going more negative than a value (set by A11-R42) corresponding to about 11 db below full band leveling (≈-2 V). This gives a faster response time when the rf turns on than would occur if the control voltage was allowed to go more negative.

The control voltage "minimum limit" feedback applied through A11CR1 to the common junction of A11-6 and the left-hand base of A11Q1 provides feedback when the output level is set above the maximum which allows full-band leveling. This feedback limits the excess error voltage developed during the low power portions of each sweep, to prevent A11Q7 from being saturated in an attempt to reduce the A11-15 output below the level at which minimum signal attenuation is achieved. It sets the minimum output of A11-15 to about -0.4 V. By preventing saturation in the amplifier, this feedback provides faster response and a smooth transition between leveled and unleveled portions of a sweep at high power levels where only partial-band leveling is possible.

4.24.5.2 Unleveled Operating Mode. When A11$_2$S2 is in the UNLEVELED position, it removes the "maximum limit" feedback supplied by A11CR2 and applies control feedback from A11Q10 to A11-6 as described in paragraph 4.6.4 above. The POWER LEVEL control is driven by a fixed level of about 270 mv supplied by A11$_2$R3 and A11$_2$R2.

4.24.6 UNLEVELED LIGHT OPERATION. (See Figure 4-19 and Schematic 900933.) The UNLEVELED WHEN LIT light is connected to +100 V through A11$_2$R4, and glows continually in the unleveled mode, when amplifier A4 is disconnected from the light by A11$_2$S2(D). In leveled operation A11$_2$S2-D connects the output of amplifier A4 to shunt the lamp-energizing current to ground when leveled operation occurs.

The unleveled light driver amplifier A4 operates as follows: The input stage A11Q12 receives the unleveled sensing signal from A11-20. When operation is continuously leveled over the band being swept, this sensing signal is continuously more negative than -3.75 V. This causes emitter follower A11Q12 to either be biased to cutoff (emitter output = 0 V), or to conduct so slightly that its output is less than +0.6 V. In either case, A11Q13 remains cut off because its base does not receive sufficient bias to produce conduction. With A11Q13 cut off, the A11Q14 base is driven by +15 V through A11R47. A11Q13 then conducts heavily and shunts A11-22 to ground, to extinguish the UNLEVELED light.

When operation is not leveled over the full band being swept, the unleveled sensing signal at A11-20 becomes less negative than -3.75 V over some or all of each sweep interval. These voltage excursions produce sufficient conduction in A11Q12 to base bias of A11Q14 to ground level, cutting it off and discharging capacitor A11C10. A11-20 is then no longer shunted to ground, and the UNLEVELED light is turned on. The time constant of A11R47/C10 prevents A11Q14 from conducting if operation is unleveled over any portion of the cycle. Only when the A11-20 signal is continuously more negative than -3.75 V over the full sweep (indicating leveled operation) will the UNLEVELED light stay extinguished.

4.24.7 ADDITIONAL CIRCUIT DETAILS.

4.24.7.1 Constant-current Operation of Differential Error Detector/Amplifier Stages. Differential stages A11Q1 and A11Q7/Q8 operate in the common-emitter configuration and in a constant-current mode, driven by A11Q2 and A11Q9, respectively. Constant-current operation is required to provide excellent common-mode rejection, so that 0 V differential output occurs with 0 V differential input.

4.24.7.2 Response Shaping. In the Gain Equalizing Loop, networks A11C6/A11R21, A11C7/A11R27, and A11C8/A11R26 provide proper response shaping to provide stable operation. In the Main Leveling Loop, A11C3 provides the basic 6 db/octave response roll-off. The networks A11C4/A11R9 and A11C5/A11R14 provide main loop compensation for the frequency characteristics of the Gain Equalizing Loop.

4.24.8 PIN DIODE ATTENUATOR POWER SUPPLY (See Figure 4-19 and Schematic B900930).

This supply uses 115 Vac input. The regulator components are contained on PC board 951087 (A11$_{ps}$) located in the lower right rear compartment of the chassis, adjacent to the A10

series regulator/retrace discharge PC board. The transformer $A11_{ps}T1$ and filter capactior $A11_{ps}C1$ are located on the chassis adjacent to the PC board. The 12.6 V output of $A11_{ps}T1$ is full-wave rectified by $A11_{ps}CR1$ and filtered by $A11_{ps}C1$. $A11_{ps}Q1$ regulates the output voltage to -12 V, controlled by closed-loop regulator-amplifier $A11_{ps}Q2/A11_{ps}Q3$. The output voltage is sampled by the wiper of $A11_{ps}R6$ and applied to the base of $A11_{ps}Q3$. The emitter of $A11_{ps}Q3$ is held at -4.3 V by zener diode $A11_{ps}CR2$. The V_{be} difference voltage thus establishes a low level of conduction in $A11_{ps}Q3$. This conduction increases as the output voltage tends to become less negative than -12 V. It decreases as the output voltage tends to increase to more than -12 V.

In operation, increased conduction of $A11_{ps}Q3$ produces a voltage drop across $A11_{ps}R5$ that increases the forward bias of $A11_{ps}Q2$. Increased conduction of $A11_{ps}Q2$ provides increased forward drive to regulate transistor $A11_{ps}Q1$, causing it to conduct more heavily. This produces a negative-going change in the output voltage, to correct for the voltage decrease that caused the increased conduction of $A11_{ps}Q3$. $A11_{ps}R1$ and $A11_{ps}R3$ establish basic working bias conditions for $A11_{ps}Q1$. $A11_{ps}C2$ filters the regulated output. The + output lead is connected to chassis ground, and the -12 V is used to supply operating power to the PIN diode attenuator.

4.25 ELEVATED SUPPLY.

The elevated supply is located in the top rear area of the chassis. The passive circuits of the elevated supply PC Board A12 have been illustrated and discussed individually in the paragraphs covering related circuits in the main chassis, paragraphs 4.6, 4.9, and 4.15.

The grid modulator A12Q1 is the only active stage in the elevated supply. Operating in the common-base configuration, it acts as an impedance converter and isolator for the output drive current developed by the transfer oscillator driver stage A9Q4.

After passing through A12 Q1 the drive current develops the necessary grid bias across A12R5 to operate the grid at a voltage negative with respect to the cathode (0 line). For tube cut-off, a maximum driver/modulator current of 35 ma across A12R5 produces the necessary cut-off bias of -27 V for Stewart tubes at A12-13, and the added drop across A12R4 produces the necessary cut-off bias of -61 V for Varian tubes at A12-14. If a particular Varian tube requires much lower drive voltage, this is achieved by connecting the grid to A12-13 (for -27 V drive) or by interchanging A12R4 and A12R5 and connecting the grid to A12-13 (for -37 V drive). Such changes, when made, are noted on the Addendum A sheet. Diodes A12CR5 and A12CR6 provide a voltage-limiting drop of 30 V from the -100 V supply level to prevent overvoltage conditions and protect A12Q1. Diode A12CR1 prevents the grid from ever being driven positive with respect to the cathode.

4.26 ANODE PROTECTION FUSE.

Varian BWO tubes contain a mesh-type intercepting anode (see Figure 4-20B). The power dissipation of this delicate anode electrode must not be allowed to exceed specified ratings. To protect against excess dissipation, an anode protection circuit (A19, Part No. 951155) is installed in instruments containing Varian tubes. The anode protection circuit PC board is located on the left hand side of the chassis, behind the high voltage test point board. This circuit is connected as shown in overall schematic D900845. It completes the connection between A12-4 and A12-5 to couple the anode supply voltage through to the BWO anode. Instruments (with Stewart/WJ tubes) not containing the anode protection circuit have a shunt wire connecting A12-4 and A12-5 in the elevated supply.

The anode protection circuit is set to "trip" when the current approaches 90% of the maximum anode current specified by the tube manufacturer. (This is well above the current level required for rated power output.) The Actual Trip-out factory setting is specified in addendum A. When such an anode overcurrent condition occurs, the anode-protection circuit "trips" and connects the anode voltage through a small resistance to the 0-line (which is tied to the BWO cathode). This eliminates the BWO anode-to-cathode positive bias to protect the tube and also triggers a trip-out of the high voltage supply protective circuits. Thus, the trip-out will be indicated by the turn-off of the HIGH VOLTAGE ON lamp on the front panel. After the problem is corrected, operation can be restored by pressing the RESET button.

The anode protection circuit operates as follows (see schematic B900940): The anode current drawn by the anode (A19-3) from the anode supply (A19-1) creates a voltage drop across A19R2, which is partially shunted by its own wiper. The A19-R2 wiper is set so that silicon controlled switch A19Q1 will be turned on by the voltage developed across A19R2 when the desired trip-out current level is reached. As long as A19Q1 is off and anode voltage at A19-3 is below the maximum level established for trip-out, there will be insufficient current through A19R6, so that no turn-on bias will be applied to silicon-controlled rectifier A19Q2, keeping it cut off. As long as A19Q2 is cut off, no emitter current will be available for A19Q3, and it will remain off.

When A19Q1 senses an overcurrent condition and turns on, the increased current flow through A19R6 triggers turn-on of A19Q2. Similarly, if anode voltage increases to an unsafe level, the increased current flow through A19R6 triggers turn-on of A19Q2. When A19Q2 turns on, it forward-biases A19-Q3. A19Q2 also ties the anode supply to the 0-line (and cathode) through A19R1 and A19CR1 to immediately shunt the excess current away from the anode. Turn-on of A19Q3 thus couples a signal slightly more positive than cathode voltage level to the lamp in A14DSR1, via A19-4 and A14-20. This energizes the lamp as though it were energized by A14K1 ((which would connect the same point to the HTR (+) which is tied to the cathode).

The lamp then triggers the light-sensitive resistor in A14DSR1 to turn on protection relay K3 which turns off the high voltage supplies in the instrument. Turn-off of the high voltage supplies removes power from the anode protection circuit, so it will automatically reset (if the overcurrent condition is removed) when high voltage is restored by pressing the RESET button or by normal turn-on of the line power switch.

4.27 LOW PASS FILTER (Units with Internal Sampling).

Most instruments with an internal sampler contain a low-pass filter as the first element in the rf output line from the BWO tube. This filter is a transmission-type resonant structure which attenuates rf harmonics generated by the BWO tube. Units without an internal sampler (i.e. 64(*)0 and 64(*)2 models) do not contain a low pass filter unless they contain a Varian tube type having an internal filter (see page 6-11). When external leveling is desired on instruments not having a filter, it may be necessary to add a low-pass filter externally between the RF OUTPUT jack and the external sampler to improve leveling performance. Harmonic output without the filter will be

at least 20 db down, but still may generate enough "noise" voltage at the crystal detector to degrade leveling performance at the upper end of some frequency bands.

4.28 INTERNAL SAMPLER-ATTENUATOR (64(*)4 and 64(*)5 Models Only).

The internal sampler-attenuator is the final element in the rf output line on Model 64(*)4 and 64(*)5 instruments. It consists of an rf sampler and a variable attenuator in a single microwave structure. The fixed sampler is integrated with a variable directional coupler which serves as the attenuator. The frequency response of the sampler and the variable coupler (attenuator) are matched, producing exceptionally flat output over wide frequency and attenuation ranges. The power variation with frequency from maximum leveled output throughout a control range of 20 db is ±0.5 db. Variation at minimum power, 50 db down, is typically less than ±1.5 db.

SECTION 5

MAINTENANCE

5.1 PERIODIC MAINTENANCE.

Every few months, perform the following maintenance on the Model 6400:

a. Remove all accumulated dust with forced air.

b. Visually inspect the unit for loose or broken connections, loose panel controls or connectors, improperly seated tubes, bent or broken tube pins, etc. Replace worn-out components as required.

c. Check voltages at test points as directed in Paragraph 5.2.

d. Make a performance test in accordance with the procedure of Paragraph 2.5.

CAUTION

All required lubrication is performed at the factory during assembly. Field lubrication should not be required.

5.2 VOLTAGE MEASUREMENTS AT CHASSIS TEST POINTS.

5.2.1 GENERAL. Test points are provided on the right-hand side of the Model 6400 chassis for all the low voltage supply outputs, and on the top of the chassis (at the left side) for the high voltage supply outputs, as shown in Figures 5-1 and 5-2. Test points for measurement of tube electrode voltages are provided on the Elevated Supply PC Board A12, as shown in Figure 5-1.

5.2.2 LOW VOLTAGE SUPPLY MEASUREMENTS. A check of the supply outputs should be made as the first step in a routine performance check or in locating the cause of malfunction.The low voltage supplies, listed in Group 1 of Table 5-1, should be checked first, since the high voltage supplies and most other circuits of the instrument cannot operate properly with out-of-spec low voltages. The low voltage test points are located on the right hand side of the chassis (Figure 5-2). These voltages are measured with respect to chassis ground (TP3), and any accurate digitial meter can be used.

5.2.3 HIGH VOLTAGE SUPPLY AND BWO TUBE ELECTRODE VOLTAGE MEASUREMENTS. The high voltage test points, listed in Groups 2 and 3 of Table 5-1 are located on the top of the chassis, either on the test point board at the left side or on the elevated supply near the rear of the chassis (Figure 5-1). The transfer oscillator output test point is located on the Transfer Oscillator PC Board A9, accessible through a hole in the shield at the top of the chassis near the rear (Figure 5-1).

WARNING

The high voltage test points (tip jacks) are located on top of the Model 6400 chassis and on the elevated supply. They are at high-voltage levels. Suitable high-voltage measurement techniques and extreme caution must be used. The cathode supply output is measured with respect to chassis ground, and a high-voltage voltmeter or a high-voltage probe must be used. For all other high voltage measurements, the "0" line (TP10), which is at cathode potential is the reference rather than chassis ground, and a floating voltmeter with at least 3000 volts insulation must be used. The heater supply output between TP7 and TP8 may be measured with high voltage off, using a standard meter. The lowest cathode supply output voltage, which in some instruments is low enough for measurement without an insulated meter, is obtained with a single frequency setting at the low end of the band. Other high voltage measurements should be made at this setting of the cathode supply to keep the "0 line" voltage as low as possible for safety reasons.

a. Cathode Supply Voltage. (TP6 (-) to chassis ground (+)). The proper cathode supply output voltages for the lower and upper band limit frequencies, corresponding to single-frequency settings of 0 and 100 on the logging scale, are given in Addendum A in the envelope at the rear of this manual. When a replacement BWO tube has been installed, refer instead to the manufacturer's data sheet for the tube, which should be retained in the same envelope. Make the dc voltage measurement with a high voltage digital meter or a suitable voltage-divider probe. Since the top cover must be removed for access to make this and all subsequent high voltage measurements, it is necessary to cheat the interlock switch by placing a wood block on it, to turn on the high voltage. Refer to Paragraph 5.3.6 of this manual for measurement of ripple effects.

b. Heater Voltage. (TP7 (+) to TP8 (-)). All the BWO tubes utilize less than 1.5 amperes heater current, so that the proper heater voltage with any tube loading the supply is 6.3 V ±0.1 V. It is recommended that this voltage be measured with the high voltage turned off by not cheating the interlock switch when the top panel is removed to make the measurement. If the measurement is made with high voltage on, the heater will be at cathode potial, and a floating, insulated voltmeter must be used.

c. -100 V Supply. (TP10 (+) to TP11 (-)). Voltage should be 100 ±0.1 V. For this measurement, the instrument must be operating with the FREQUENCY Mode Selector switch set to SINGLE, and with no modulation applied. The measurement must be made using a floating, insulated voltmeter.

d. Anode Supply. (TP9 (+) to TP10 (-)). The proper anode supply voltage output setting is given in Addendum A in the envelope at the rear of this manual. When a replacement BWO tube has been installed, refer instead to the manufacturer's data sheet for the tube, which should be retained in the same envelope. The measurement must be made using a floating, insulated voltmeter.

e. Grid Voltage. (TP10 (+) to A12TP3 (-)). Voltage should be ≈ 0V with controls set for RF ON (unmodulated); and 61 ±10 V (for Varian BWO tubes; less if noted on Addendum A) or 27 ±2 V (for Stewart or WJ BWO tubes) with the FREQUENCY Mode Selector switch in the OFF position. The measurement must be made using a floating, insulated voltmeter.

f. Collector Current.

Instruments Having Varian BWO tubes: Collector current cannot be measured on Varian BWO tubes. All beam current is intercepted by the helix. The "Collector

(paragraph 5.2.3 continued on page 5-8)

A. TYPICAL INSTRUMENT WITH PIN DIODE LEVELING AND INTERNAL SAMPLER

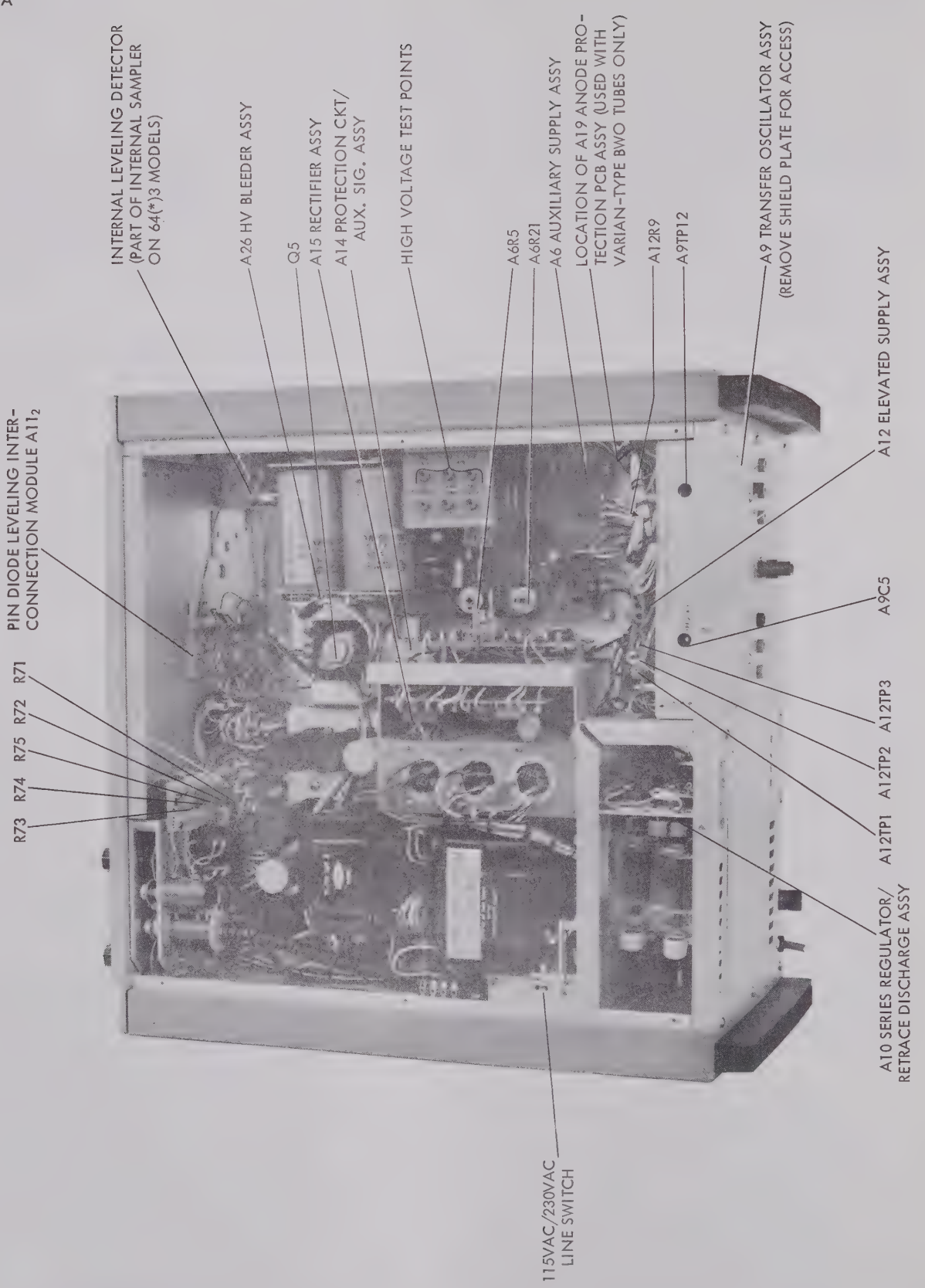
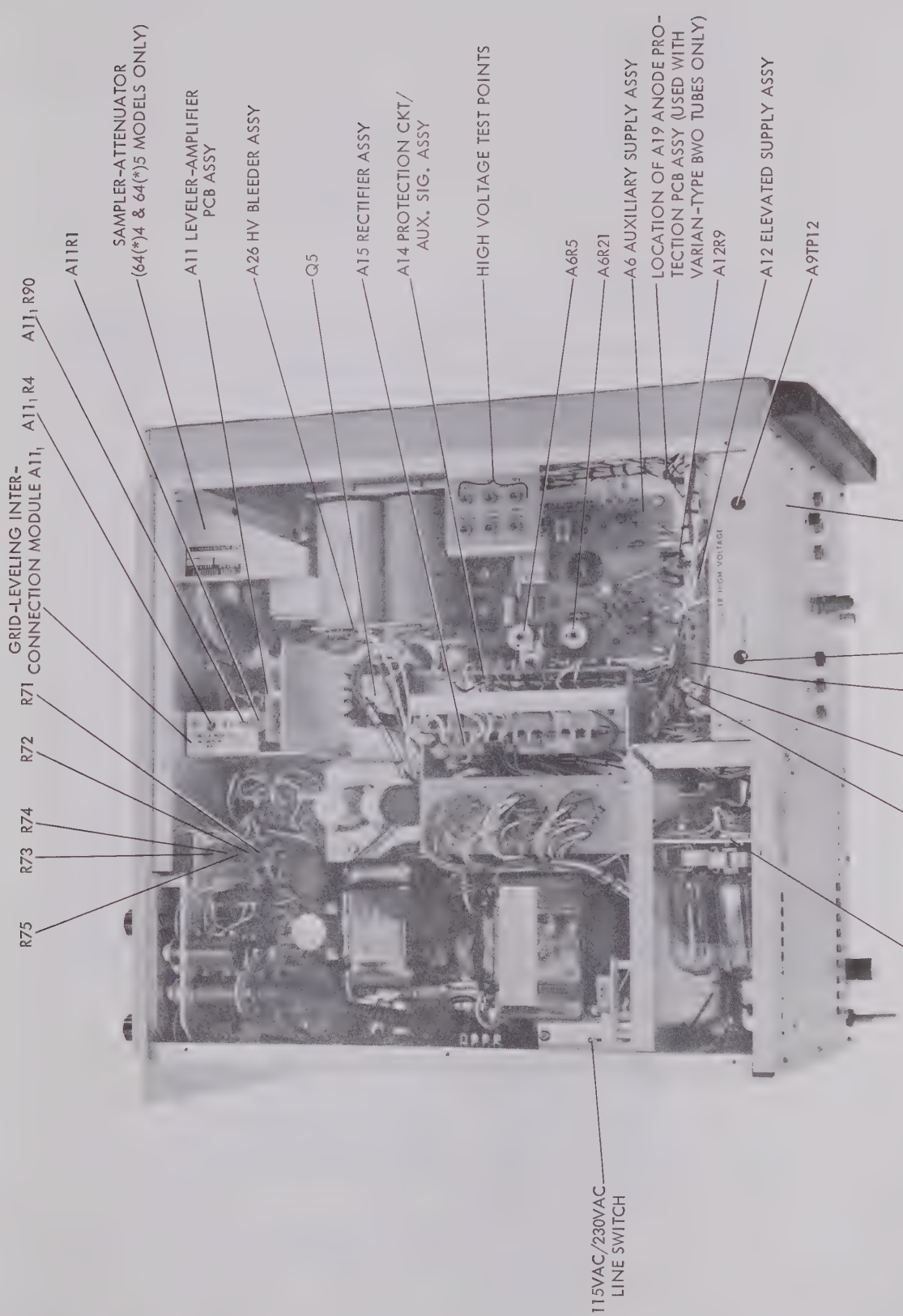


Figure 5-1. Top View of Chassis with Top Cover Removed.
(Sheet 1 of 2)



B. TYPICAL INSTRUMENT WITH GRID LEVELING AND INTERNAL SAMPLER - ATTENUATOR

Figure 5-1. Top View of Chassis with Top Cover Removed.
(Sheet 2 of 2)

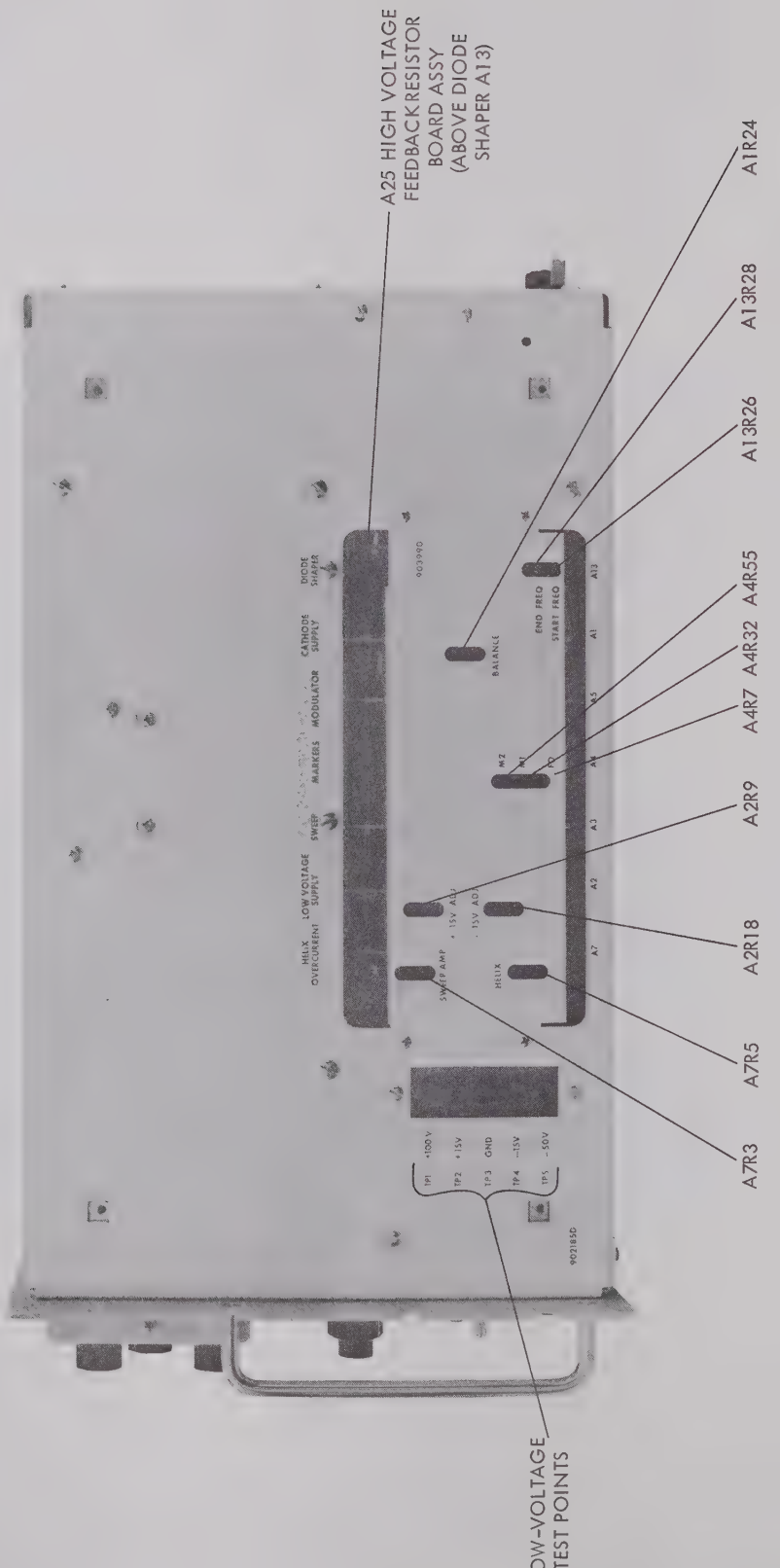
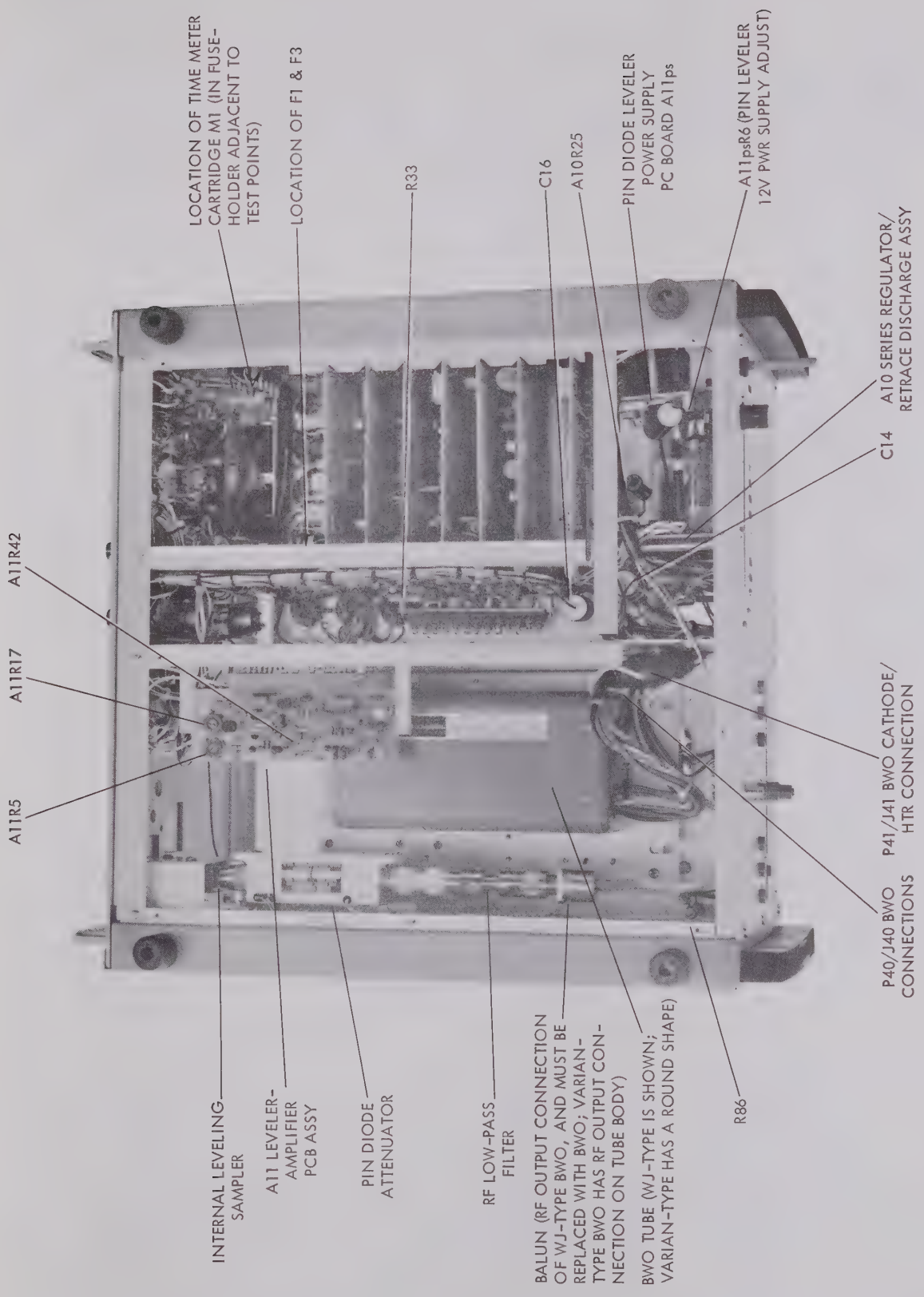
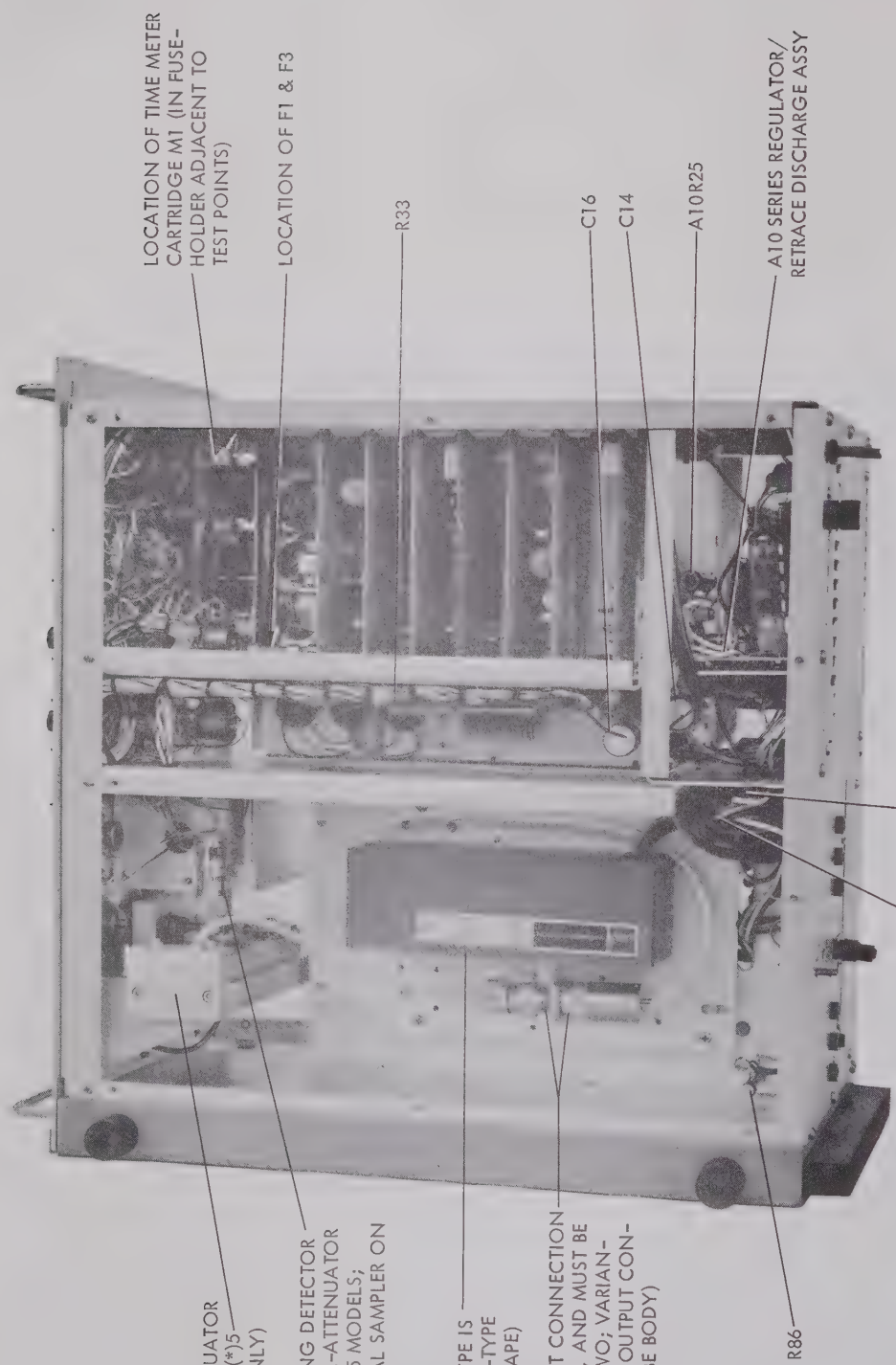


Figure 5-2. Right Side View of Instrument with Side Panel Removed.


LOCATION OF TIME METER CARTRIDGE M1 (IN FUSE-HOLDER ADJACENT TO TEST POINTS)
LOCATION OF F1 & F3
R33
C16
A10R25
PIN DIODE LEVELER POWER SUPPLY PC BOARD A11ps
A11psR6 (PIN LEVELER 12V PWR SUPPLY ADJUST)
A11R42
A11R17
A11R5
C14
A10 SERIES REGULATOR/ RETRACE DISCHARGE ASSY
P41/J41 BWO CATHODE/ HTR CONNECTION
P40/J40 BWO CONNECTIONS
INTERNAL LEVELING SAMPLER
A11 LEVELER-AMPLIFIER PCB ASSY
PIN DIODE ATTENUATOR
RF LOW-PASS FILTER
BALUN (RF OUTPUT CONNECTION OF WJ-TYPE BWO, AND MUST BE REPLACED WITH BWO; VARIAN-TYPE BWO HAS RF OUTPUT CONNECTION ON TUBE BODY)
BWO TUBE (WJ-TYPE IS SHOWN; VARIAN-TYPE HAS A ROUND SHAPE)
R86

A. TYPICAL INSTRUMENT WITH PIN DIODE LEVELING AND INTERNAL SAMPLER

Figure 5-3. Bottom View of Chassis with Bottom Cover Removed. (Sheet 1 of 2)


LOCATION OF TIME METER CARTRIDGE M1 (IN FUSE-HOLDER ADJACENT TO TEST POINTS)
LOCATION OF F1 & F3
R33
C16
C14
A10R25
A10 SERIES REGULATOR/ RETRACE DISCHARGE ASSY
P41/J41 BWO CATHODE/ HTR CONNECTION
P40/J40 BWO CONNECTIONS
SAMPLER-ATTENUATOR (64(*)4 & 64(*)5 MODELS ONLY)
INTERNAL LEVELING DETECTOR (PART OF SAMPLER-ATTENUATOR ON 64(*)4 & 64(*)5 MODELS; (PART OF INTERNAL SAMPLER ON 64(*)1 MODELS)
BWO TUBE (WJ-TYPE IS SHOWN; VARIAN-TYPE HAS A ROUND SHAPE)
BALUN (RF OUTPUT CONNECTION OF WJ-TYPE BWO, AND MUST BE REPLACED WITH BWO; VARIAN-TYPE BWO HAS RF OUTPUT CONNECTION ON TUBE BODY)
R86

B. TYPICAL INSTRUMENT WITH GRID LEVELING AND INTERNAL SAMPLER - ATTENUATOR

Figure 5-3. Bottom View of Chassis with Bottom Cover Removed. (Sheet 2 of 2)

Table 5-1. Test Point Measurements

GROUP 1 - Measured with Respect to Ground (TP3) with Standard Digital Meter (Listed in Preferred Order of Measurement).

Supply	TP#	DC Voltage & Tolerance	AC Ripple
-15 V*	TP4	-15.0000 ± 0.0075 V	500 μv maximum
+15 V*	TP2	+15.0000 ± 0.0075 V	500 μv maximum
+100 V	TP1	+100.0 ± 3.0 V	2 mv maximum
-50 V	TP4	-50 ± 5 V	2 mv maximum

GROUP 2 - Measured with Respect to Ground (TP3 or Chassis) with High Voltage Digital Meter or Suitable Voltage-Divider Probe.

Supply	TP#	DC Voltage & Tolerance	AC Ripple
Cathode*	TP6	(-150 to -2500 V; refer to Addendum A in the envelope at the rear of this manual for the specific range.)	<0.01% of supply output voltage

GROUP 3 - Measured Between Two Test Points, Requiring Use of a Floating, Insulated Voltmeter (Listed in Preferred Order of Measurement).

Supply	TP# to TP#	Voltage	Notes
Heater* (voltage)	TP7 (+) TP8 (-)	6.3 V ± 0.1 V (with 1 ampere load)	Measure with high-voltage off.
-100 V*	TP10 (+) TP11 (-)	100 ± 0.1 V	FREQUENCY Mode Selector switch on SINGLE, no modulation
Anode*	TP9 (+) TP10 (-)	30 to 280 V, depending upon BWO tube used.**	Voltage is set by means of feedback controlled by a factory-selected resistor in the elevated supply. (See Figure 5-4.)
Transfer Oscillator Output	A9TP12 (+) TP11 (-) (A9TP12 is TRANSFER OSCILLATOR OUTPUT test point)	0 to 5 V	0 V with tube supplying unmodulated rf output. 5 V with FREQUENCY Mode Selector switch in OFF position.
Grid	TP10 (+) A12TP3 (-) (A12TP3 is located on the Elevated Supply PC Board)	27 ±2 V (units with Stewart/WJ Tubes)	With controls set for RF OFF
		61 ±6 V (units with Varian Tubes)	With controls set for RF OFF
		< 1 V	With controls set for RF ON

*This supply may be field-adjusted. Follow the procedure given in Paragraph 5-3.
**See paragraph 5.2.3d for correct value and measurement procedure.

Current" test point (A12TP1) on instruments containing Varian tubes is non-functional.

Instruments Having Stewart (W-J) BWO tubes: (TP1 (+) to A12TP1 (-)). The proper collector currents in ma for the lower and upper band limit frequencies, corresponding to single-frequency settings of 0 and 100 on the logging scale, are given in Addendum A in the envelope at the rear of this manual. When a replacement BWO tube has been installed, refer instead to the manufacturer's data sheet for the tube, which should be retained in the same envelope.

To measure the collector current, measure the voltage drop between TP1 (+) and A12TP1 (-). This is the voltage drop produced across a 10-ohm resistor by the collector current. Hence, the voltage measured in millivolts must be divided by 10 to obtain the current in milliamperes.

CAUTION

This voltage measurement is at the level of +100 V, since TP1 is the +100 V test point. Thus, the voltmeter used must be floating, but need not be a high-voltage unit.

g. Helix Current. (A12TP2 (-), TP3 or chassis ground (+)). The proper helix currents in ma for the lower and upper band limit frequencies, corresponding to single-frequency settings of 0 and 100 on the logging scale, are given in Addendum A in the envelope at the rear of this manual. When a replacement tube has been installed, refer instead to the data sheet for the new tube, which should be retained in the same envelope.

NOTE: The helix overcurrent trip-out level is listed in Addendum A.

Instruments Having Varian BWO tubes: To measure the helix current, measure the voltage drop between A12TP2 and TP3 (or chassis ground) with the controls set for RF ON (unmodulated). This is the voltage drop produced across a 10-ohm resistance by the helix current. Hence, the voltages measured in millivolts must be divided by 10 to obtain the current in milliamperes. This voltage measurement is at ground level so that a floating or high voltage voltmeter need not be used.

Instruments Having Stewart (WJ) BWO Tubes. To measure the helix current, measure the voltage drop between A12TP2 and TP3 (or chassis ground) with the controls set for RF ON (unmodulated). This is the voltage drop produced across a 100 Ω resistance by the helix current. Hence, the voltage measured in millivolts must be divided by 100 to obtain the current in milliamperes. This voltage measurement is at ground level so that a floating or high-voltage voltmeter need not be used.

h. Anode Current. (To be measured only on instruments having Varian BWO Tubes.) The maximum allowable anode current and voltage are listed in Addendum A. On units having an anode protection circuit, the current trip-out level is indicated on Addendum A. Operating current level is typically well below the maximum value. To measure the anode current, use a clip-on milliammeter to monitor current in the red lead which connects to terminal 5 of the Elevated Supply PC Board A12.

5.3 INTERNAL ADJUSTMENTS.

CAUTION

Before attempting to make ANY adjustments of chassis calibration controls, read all the material under this heading. Improper adjustments can degrade the accuracy of the instrument.

5.3.1 AVAILABLE ADJUSTMENTS. There are 24 internal adjustments in the Model 6400. This instrument is designed for long-term operation with a minimum of adjustment. The 24 adjustments include 11 "critical" adjustments which should not need field adjustment unless components are replaced in the critical circuits calibrated by these adjustments. The other 13 adjustments consist of (a) Supply Calibration Adjustments (b) RF Performance Calibration Adjustments, and (c) Frequency Calibration Adjustments, which can be used for periodic recalibration at six-month intervals or as required. These four different classes of adjustments, and their uses, are described separately in Paragraphs 5.3.2, 5.3.3, 5.3.4, and 5.3.5. See Figures 5-1 and 5-2 for location of adjustments.

5.3.2 CRITICAL ADJUSTMENTS. The critical adjustments can degrade factory calibration accuracy if adjusted without specialized calibration techniques. These critical adjustments are located in stabilized circuits protected against in-service component variations. They should not require any further adjustment in the field unless damage or component failure occurs in the critical circuits calibrated by these adjustments. If calibration is required because of replacement of parts in a critical circuit, the optimum manner of performing the critical adjustments is specified in the calibration procedures given in this manual.

A factory calibration service is available at nominal cost by returning the instrument to ALFRED. Contact your nearest representative or our sales department.

The critical adjustments and the circuits they calibrate are described below:

NOTE: Some of the adjustment methods outlined below utilize frequency-standardization techniques to determine when the correct adjustment is obtained. For single-band sweepers, this is preferable to voltage-standardization techniques, since it assures that the essential output parameter - frequency - is calibrated.

1. A1R24 BALANCE adjustment, located in the cathode supply (access thru PC board retaining plate, Figure 5-2). This adjustment is used to balance the base-emitter voltages of the input dual transistor A1Q1. These voltages do not change with age. Readjustment is required only when A1Q1 is replaced. At that time, A1R24 should be carefully set by performing the procedure of paragraph 5.3.5, and adjusting A1R24 INSTEAD OF A13R26 in steps h and i when calibrating the "0%" frequency.

2. A1R38 MAX CAL adjustment, located in the cathode supply (access thru PC board retaining plate, Figure 5-2). This adjustment corrects for value variations in the 15 K Ωsumming resistors, and the factory setting should not be changed. Factory calibration is performed after the control voltages provided by all five dial potentiometers have been standardized. With the instrument dial set for single-frequency output at the high band-edge frequency, the MAX CAL is adjusted until the output frequency is correct. Readjustment is required only when a summing resistor is replaced, to bring frequency output performance (as measured with a wavemeter) within tolerance throughout the band, in accordance with paragraph 5.3.5.

3, 4, 5. A4R7, A4R32 and A4R55 MARKER adjustments (Figure 5-2). These adjustments are used to correct errors due to variations in the base-emitter voltage of the input transistors A4Q1, A4Q7, and A4Q13, and to compensate for any variations in the values of the summing resistors. The parameters compensated for do not change with age, and the factory adjustment should not be reset unless parts are replaced. After parts replacement, readjust only the one calibration control corresponding to the channel in which the input transistor or summing resistor has been replaced. Readjust the repaired channel so that the frequency at which its marker is generated (as measured with a wavemeter) tracks the output of the other marker channels when set to the same dial frequency. The adjustment should be set for optimum performance across the band.

6 thru 10. R71, R72, R73, R74, and R75, the calibration adjustments for the F_2, M_2, F_1, M_1, and F_0 panel controls (on "In-Voltage Calibrate" PC Board 950853 behind the front panel, Figure 5-1). These adjustments are used to electrically correct any errors due to mechanical tolerance build-up in the dial mechanism. The electrical and mechanical design of the dial mechanism offers excellent stability and realiability, and alteration of the factory-set calibration should never be required until parts replacement is required after long service. When the output frequency appears not to be calibrated to the dial settings, refer to the trouble-shooting chart, Table 5-2, to localize the source of the trouble. The dial mechanism and dial control potentiometers are the least likely cause of improper calibration, provided the factory adjustment of the mechanism itself and of these five calibration resistors has not been altered.

After replacing a particular FREQUENCY or MARKERS potentiometer or making a repair in the control mechanism for a particular dial indicator, adjust only the calibration resistor for that control. The electrical adjustment is primarily intended for calibration of the intermediate and high-band portions of the control range, after mechanical adjustments have been made on the affected channel to achieve proper calibration at the low end of the band. Adjust the calibration resistor for the repaired channel so that its single-frequency performance (as measured with a wavemeter) matches that of the other controls when set to the same dial frequency. Calibration must be checked carefully for optimum performance across the full band. If more than one dial channel must be calibrated, it is recommended that the instrument be returned to the factory for dial calibration.

11. A9C5, TRANSFER OSC. FREQ. ADJ. (Figure 5-1). This adjustment is made at the factory and should not need further adjustment unless one of the critical components is replaced. The critical components are A9Q1, A9Q2, A9Q3, A9L3, A9C3, A9C4, A9C5, A9C8 or A9T1. An adjustment procedure is given in Step 3.c of Table 5-10. Failure in the transfer oscillator due to inadvertent short-circuiting of components by improper use of a metallic screwdriver will normally be limited to the demodulator and output driver circuits driven by A9T1. Replacement of components in those circuits does not require adjustment of A9C5.

5.3.3 PERIODIC SUPPLY RECALIBRATION ADJUSTMENTS. The following adjustments may be carefully checked and field-set to perform periodic recalibration. They should also be used for calibration after replacement of parts in the associated supplies. Because the accuracy and stability of the supply circuits in the Model 6400 approach that of the best test equipment, only test equipment that has recently been calibrated should be used to check the Model 6400. When the measured value falls anywhere within the tolerance range indicated, no adjustment should be performed.

1. A2R18 -15 V ADJ. (Figure 5-2) is used to set the -15 V supply output at TP4 to -15.0000 V dc ± .0075 V dc with respect to chassis ground (TP3). When checking or making this adjustment a .01% digital voltmeter with at least five digits should be used. The digital voltmeter should have been recently calibrated. This adjustment should be checked after replacing A2Q8 or associated components shown in Figure 4-3.

2. A2R9 +15 V ADJ. (Figure 5-2) is used to set the +15 V supply output at TP2 to +15.0000 V dc ± .0075 V dc, with respect to chassis ground (TP3). Before checking or making this adjustment the -15 V supply must be checked, as the -15 V is used as the reference for the +15 V supply. A .01% digital voltmeter accurate to at least five digits should be used. This adjustment should be checked after replacing A2Q4 or associated components shown in Figure 4-4.

3. A6R21 HEATER ADJ. (Figure 5-1) is used to set the heater supply output between TP7 and TP8 to 6.3 V dc ± 0.1 V dc when the supply is loaded to 1 ampere and the input line voltage is nominal (115 VAC). When making this adjustment the high voltage should be turned off by not cheating the top cover plate interlock switch when the top plate is removed for measurement access. This is required for access as shown in Figure 5-1. If the high voltage is turned on during this measurement, a floating voltmeter with at least 3000 V insulation must be used. The voltmeter used should have an accuracy of at least 1%. The adjustment of A6R21 should be checked after replacing Q5, A6Q6, A6Q7, A6CR3, or associated components shown in Figure 4-9.

WARNING

When the high voltage is present, extreme caution is required. For personnel protection a non-metallic screwdriver must be used.

4. A6R5 -100 V ADJ. (Figure 5-1) is used to set the -100 V floating supply to -100 V dc ±0.1 V dc. It should be checked after replacement of A6Q4 or A6Q5 or associated components shown in Figure 4-12.

WARNING

When making this adjustment the high voltage must be turned on by using a wood block to cheat the top cover interlock switch. Extreme care should be used in the procedure. Use a non-metallic screwdriver for safety.

The following procedure permits making this adjustment without using a floating voltmeter, by making all measurements with respect to chassis ground.

a. Since the voltages to be measured are referenced to the cathode supply voltage, reduce this voltage to a minimum value by turning the FREQUENCY Mode Selector switch to SINGLE, the SINGLE Frequency Selector switch to F_0, and the F_0 FREQUENCY control to the low-frequency end of the dial. Turn the MODULATION

switch to AM OFF.

b. Measure the voltage between the 0 LINE, at TP10 and the -100 V supply output, at TP11, with a 0.01% floating, insulated digital voltmeter. (This voltage for some instruments can be as high as 2000 V below ground; refer to Addendum A for applicable values.)

c. The voltage measured in Step b should be -100.0 V ±0.1 V. Adjust A6R5, if necessary, to achieve this output level.

5. A7R5 HELIX OVERCURRENT TRIP-OUT adjustment (Figure 5-2) is used to set the trip-out point. The basic trip-out current is 1 ma through A7R10. For other values of trip-out current, A7R10 is shunted by a resistor in the elevated supply. Thus, the standard calibration of 1 ma through A7R10 applies regardless of the frequency band of the instrument. This adjustment should be checked after replacement of A7Q1, A7Q2, A7Q3 or associated components shown in Figure 4-10.

To set the helix trip-out point, proceed as follows with the high voltage off:

a. Connect a 10K potentiometer and 10K ohm 1% resistor in series between terminal A7-H and the -15 V supply (TP4). (See circuit sketch below.)

b. Adjust the 10 K pot so that the voltage developed between A7-H and chassis ground is 49.9 millivolts.

c. Adjust A7R5 so the relay A7K1 de-energizes when the voltage at A7-H exceeds 49.9 mv.

d. Disconnect the test circuit.

NOTE: If helix overcurrent trip-out occurs, press RESET button after eliminating overcurrent condition.

6. A7R3 SWEEP AMPLITUDE adjust (Figure 5-2) is used to set the peak amplitude of the +15 V sweep voltage. This adjustment should not be attempted unless it has definitely been established that the peak amplitude of the sweep is not correct. This can be done by making two frequency measurements, and the actual adjustment should be carried out in terms of frequency performance, as follows:

a. Set the FREQUENCY Mode Selector to SINGLE, the SINGLE Frequency Selector to F_2, the F_2 FREQUENCY control to 100 on the logging scale, and the F_1 control to 0 on the logging scale. Turn the MANUAL SWEEP control to the F_2 switched position.

b. Measure the output frequency using a wavemeter.

c. Set the FREQUENCY mode selector to SWEEP ($F_1 \rightarrow F_2$). Use the .1 second calibrated sweep and set the TRIGGER switch to LINE. Leave other controls as set in Step a.

d. Measure the frequency at the end of the sweep.

e. The frequency measured in Steps b. and d. should be the same to within ±0.5%. If not, repeat Step d. and adjust A7R3 to bring the measured frequency within the required limits.

5.3.4 PERIODIC RF PERFORMANCE CALIBRATION ADJUSTMENTS. There are six field-adjustable internal rf performance calibration adjustments. The instrument is designed for long-term operation with a minimum of adjustment. The main purpose of the adjustments provided is to simplify the recalibration of the instrument after installation of a new BWO tube or other components. These adjustments can also be used for periodic recalibration at six-month intervals or as required. The adjustments and a recommended adjustment procedure for each, are described below. These procedures permit the instrument to be calibrated to meet published specifications, when the Model 6400 supplies have been calibrated in accordance with the procedures given above.

A factory calibration service is available at nominal cost by returning the instrument to ALFRED. Contact your nearest representative or our sales department.

WARNING

It will be necessary to remove the instrument top cover for access to these adjustments. Then "cheat" the cover interlock switch by resting a wood block on it to turn on the high voltages which are required to operate the BWO tube. Exercise extreme caution when working near the exposed live circuits.

CAUTION

Use a non-metallic screwdriver in making any required adjustments. Use of a metallic screwdriver can

(1) Damage magnetic focus of microwave tube
(2) Cause circuit-damaging shorts in the area between the access opening and the adjustment screw.

1. A12R9 ANODE ADJUST (Power Calibration) Adjustment. This control is used for fine adjustment of the anode voltage supplied to the BWO tube, after installation of the proper-value resistor in the A12R14 circuit position. Re-adjustment will usually be required when the BWO tube is replaced, and may also be useful to restore the power output level of an aging BWO tube. The final criteria of a proper anode voltage adjustment (assuming other voltages are correct) is that rated power output is obtained. Thus, the final adjustment of anode voltage should be made in terms of output power, in accordance with the following procedure.

a. For newly installed BWO tubes, check and adjust the anode voltage to the specified level using the ANODE ADJ control as directed in steps b through e. For adjustment of older tubes, start with step f.

b. Determine the operating value for anode voltage specified in Addendum A (located in the envelope at the rear of this manual). Use this voltage value and the graph given in Figure 5-4 to determine the correct value for feedback resistor A12R14 at the top of the elevated supply PC board.

c. If the value of A12R14 determined in Step a differs from the resistor actually installed in the unit, change A12R14 to the proper value.

d. Measure the anode voltage between TP9 (+) and TP10 (-), using a floating, insulated meter, and adjust it to the value determined in Step a, by using A12R9 ANODE ADJ.

CAUTION

This is a high-voltage measurement. Use a floating, insulated voltmeter.

e. Proceed with steps f-j for a final adjustment of anode voltage in terms of output power.

f. Connect an rf test loop consisting of a suitable attenuator pad, a thermistor mount, and a power meter to the RF OUTPUT jack to measure absolute power. Be sure to use a large enough attenuator to avoid exceeding the thermistor power rating. Alternately, an ALFRED 8000/7051 Oscilloscope/Sweep Network Analyzer system can be used for making direct absolute power measurements with a crystal detector.

g. Make the following control settings:

RF OUTPUT to UNLEVELED
FREQUENCY Mode Selector to SWEEP $F_1 \rightarrow F_2$
MARKER AMPLITUDE to OFF
MODULATION to AM OFF
SWEEP TIME to 10
SWEEP TRIGGER to FREE RUN
F_1 to 0 on the logging scale
F_2 to 100 on the logging scale

h. Observe the unleveled power output characteristic. If power at any point in the sweep is below the level specified in Table 1-1, increase the anode voltage slightly using the ANODE ADJ control.

NOTE: The ANODE ADJ. control permits an adjustment range of about ±10 V. To provide a greater adjustment, particularly to restore the tube power output level after long service, it may be necessary to raise the anode voltage by more than the amount available from the ANODE ADJ. control. To do this, substitute a slightly higher resistance value for A12R14 (see Figure 5-4).

WARNING

Turn power off when changing A12R14.

CAUTION

Do not increase the anode supply voltage more than necessary to bring the minimum power point up to specifications. If rated power output cannot be obtained with a reasonable anode voltage, and other tube operating voltages are correct, the BWO tube must be replaced. Also, helix current must not be allowed to exceed the specified maximum (trip out) level. Any increase in anode voltage over the factory setting shown in Addendum A will reduce the operating life of the BWO tube.

In addition, for instruments having Varian tubes, the anode supply voltage should never be adjusted so that this voltage, monitored as described in Paragraph 5.2d, exceeds the maximum operating level shown in Addendum A or the tube data sheet. Anode current in Varian tubes (monitored as described in Paragraph 5.2h) must not be allowed to exceed 10 ma (or the maximum current rating specified in Table 5-12 for instruments with the anode protection circuit). Exceeding the voltage or current limits for the anode voids the warranty!

i. For units with internal sampling, set the RF OUTPUT control to LEVELED and the RF SAMPLER switch to INT. Then check the leveled power characteristic across the band, and also check leveler response to the POWER LEVEL control. The maximum power output obtainable with full-band leveling should occur at a mid-range setting of the POWER LEVEL control, and should equal or exceed the level specified in Table 1-1. Also check the leveled power variation across the band. The variation across the entire band should not exceed the amount specified in Table 1-1. On PIN-leveled units, if the unit does not meet leveled output specifications, check the INTERNAL SAMPLER SENSITIVITY and CONTROL VOLTAGE LIMIT adjustments as directed in Paragraph 5.3.4. On grid-leveled units, if the unit does not meet leveled output specifications, check the LEVELER BALANCE and INTERNAL SAMPLER SENS. adjustments per Par. 5.3.4.

j. For units which require external sampling, set the RF OUTPUT control to LEVELED. Connect a suitable external rf sampler loop to drive the RF SAMPLER INPUT jack, as shown in Figure 5-5, by inserting a sampler or a coupler and detector between the RF OUTPUT jack and the attenuator pad. With a suitable sampler and a proper adjustment of the RF SAMPLER SENS. panel control, it should be possible to obtain full-band leveling with a mid-range setting of the POWER LEVEL control; and response to adjustment of the POWER LEVEL control above and below the full-band leveling point should be as described in Section 3. The maximum power output obtainable with full-band leveling should approximately equal the level specified in Table 1-1. (An optimum external sampler loop using flat components can achieve the minimum variation specifications given in Table 1-1.) On PIN-leveled units, if leveler performance is unsatisfactory and the external sampler loop is known to be adequate, check the CONTROL VOLTAGE LIMIT adjustment as directed in Paragraph 5.3.4. On grid-leveled units, if leveler performance is unsatisfactory and the external sampler loop is known to be adequate, check the LEVELER BALANCE adjustment per paragraph 5.3.4.

2.,3. A13R26 START FREQ and A13R28 END FREQ. Adjustments. These controls are used to set the cathode supply feedback limits to obtain the proper cathode supply output voltage limits for the BWO tube, corresponding to the lower and upper frequency limits of the instrument. The proper voltages for these band limits can be checked as described in Paragraph 5.2.3. a above.

Adjustment of these voltages to the prescribed values is the first step in frequency calibration. Final frequency calibration involves a further adjustment of A13R26 and A13R28 to obtain calibrated frequency performance. Once final frequency calibration of the instrument has been carried out using the procedure given in Paragraph 5.3.5, these voltages should not be re-adjusted.

Refer to Paragraph 5.3.5 for the proper procedure.

4. INTERNAL SAMPLER SENSITIVITY Adjustment. This adjustment is A11R17 on PIN-leveled instruments (64(*)3 and 64(*)5 series) and is R90 on grid-leveled instruments (64(*)1 and 64(*)4 series). This control is used to set the signal leveler applied to the leveler-amplifier from the internal rf sampler. The proper adjustment for standard applications is one that places the full-band leveling point at about the center of

the adjustment range of the red POWER LEVEL control, and provides unleveled output with the POWER LEVEL control turned fully CW. This allows the POWER LEVEL control to be set above the full-band-leveled position for higher-level, partial-band leveling, and also provides an adjustment range of ≈ 5 db (grid-leveled units) or ≈10 db (PIN-leveled units) below full-band-leveled power when the POWER LEVEL control is turned fully CCW. Note that this control affects only operation with the internal rf sampler. When an external sampler is used, the front panel RF SAMPLER SENS. control provides a similar adjustment function. To achieve the maximum available amount of controlled reduction below the full-band-leveled point, a readjustment of the MINIMUM POWER LIMIT control may also be required. (This MINIMUM POWER LIMIT control is A11R5 on PIN-leveled units and $A11_1$ R4 on grid-leveled units).

The adjustment procedure is as follows:

a. Connect the RF OUTPUT jack through a suitable attenuator to a crystal detector, and connect the detector output to the vertical channel of an oscilloscope. Use the OUTPUT SWEEP signal to drive the horizontal channel of the oscilloscope.

b. Make the following control settings:

RF OUTPUT to LEVELED
RF SAMPLER to INT
FREQUENCY Mode Selector to SWEEP $F_1 \rightarrow F_2$
MARKER AMPLITUDE to OFF
MODULATION to AM OFF
SWEEP TIME to .01
SWEEP TRIGGER to FREE RUN
F_1 to 0 on the logging scale
F_2 to 100 on the logging scale
Red POWER LEVEL fully CW
ATTENUATOR (if present) to 0

c. Adjust the INTERNAL SAMPLER SENS adjustment until the maximum-power excursion of the unleveled CRT presentation appears flattened, indicating the start of leveled response. Then back off the adjustment so that the unleveled trace remains unaffected with the red POWER LEVEL control remaining fully CW.

d. Turn the red POWER LEVEL control CCW slowly and observe the onset of leveled performance across the band. Full-band leveling should be achieved at a midrange setting of the POWER LEVEL control.

e. With the red POWER LEVEL control set at the maximum power level that allows full-band-leveling, adjust the oscilloscope vertical amplification to obtain a full-height presentation on the CRT.

f. Turn the red POWER LEVEL control fully CCW. With the oscilloscope amplification set as above, and the input to the crystal detector attenuated sufficiently that square-law operation is assured, the presentation on the CRT should be reduced to less than 1/3 (grid-leveled units) or 1/10 (PIN-leveled units) of the amplitude observed in Step e. If not, adjust the MINIMUM POWER LIMIT adjustment (A11R5 on PIN-leveled units; $A11_1$ R4 on grid-leveled units) to achieve such a reduction in level.

NOTE: On PIN-leveled units, if the adjustment of A11R5 seems to "bottom out" with insufficient range, turn the CONTROL VOLTAGE LIMIT adjustment A11R42 fully CW to permit adjustment of the MINIMUM POWER LIMIT. Then refer to item 6 below to properly adjust the CONTROL VOLTAGE LIMIT.

5. MINIMUM POWER LIMIT Adjustment. This adjustment is A11R5 on PIN-leveled instruments (64(*)2, 64(*)3, and 64(*)5, and is $A11_1$ R4 on grid-leveled instruments 64(*)0, 64(*)1, and 64(*)4. This control is used to set the range of the red POWER LEVEL control by adjusting its lower limit. It does not affect the upper limit of the control range.

The adjustment procedure for units with internal sampling is included as the final step in the INTERNAL SAMPLER SENS adjustment procedure, item 4 above. For units without internal sampling, use the following procedure:

a. Connect a suitable external sampler loop, consisting of a sampler or a directional coupler and detector, to the RF OUTPUT jack, and use the sampler output to drive the RF SAMPLER INPUT jack (see Figure 5-5). Terminate the rf loop with a suitable attenuator and crystal detector, and connect the detector output to the vertical channel of an oscilloscope. Use the OUTPUT SWEEP signal to drive the horizontal channel of the oscilloscope.

b. Make the following control settings:

RF OUTPUT to LEVELED
RF SAMPLER to EXT
FREQUENCY Mode Selector to SWEEP $F_1 \rightarrow F_2$
MARKER AMPLITUDE to OFF
MODULATION to AM OFF
SWEEP TIME to .01
F_1 to 0 on the logging scale
F_2 to 100 on the logging scale
Red POWER LEVEL fully CW

c. Adjust the front panel RF SAMPLER SENS control until the maximum-power excursion of the unleveled CRT presentation appears flattened, indicating the start of leveled response. Then back off the adjustment so that the unleveled trace remains unaffected with the red POWER LEVEL control remaining fully CW.

d. Turn the red POWER LEVEL control CCW slowly and observe the onset of leveled performance across the band. Full-band leveling should be achieved at a mid-range setting of the red POWER LEVEL control.

e. With the red POWER LEVEL control set at the maximum power level that allows full-band-leveling, adjust the oscilloscope vertical amplification to obtain a full-height presentation on the CRT.

f. Turn the red POWER LEVEL control fully CCW. With the oscilloscope amplification set as above, and the input to the crystal detector attenuated sufficiently that square-law operation is assured, the presentation on the CRT should be reduced to less than 1/3 (grid-leveled units) or 1/10 (PIN-leveled units) of the amplitude observed in Step e. If not, adjust the MINIMUM POWER LIMIT adjustment to achieve such a reduction in level.

NOTE: On PIN-leveled units, if the adjustment of A11R5 seems to "bottom out" with insufficient range, turn the CONTROL VOLTAGE LIMIT adjustment A11R42 fully CW to permit adjustment of the MINIMUM POWER LIMIT. Then refer to item 6 below to properly adjust the CONTROL VOLTAGE LIMIT.

6. A11R42 CONTROL VOLTAGE LIMIT Adjustment (only on PIN-leveled instruments 64(*)2, 64(*)3, and 64(*)5). This adjustment is used to set the quiescent leveler attenuation whenever rf output is modulated off, by setting the limiting amount of controlling feedback supplied in the absence of rf signal. The operating characteristics do not change with age. Unless the factory adjustment is altered improperly, readjustment should not be required unless the PIN attenuator or A11Q1 are replaced. At that time, A11R42 should be carefully set to provide a proper balance between the extremes of (1) producing excess overshoot in square wave modulation, and (2) interfering with smooth leveling at low power levels.

To adjust the CONTROL VOLTAGE LIMIT, proceed as follows after having set the MINIMUM POWER LIMIT in accordance with item 5 above:

a. Make the following control settings:

RF OUTPUT to LEVELED
FREQUENCY Mode Selector to SWEEP $F_1 \rightarrow F_2$
MARKER AMPLITUDE to OFF
MODULATION to AM OFF
SWEEP TIME to .1
SWEEP TRIGGER to FREE RUN
F_1 to 0 on the logging scale
F_2 to 100 on the logging scale
POWER LEVEL (red) fully CCW

b. If the unit has internal sampling, switch the RF SAMPLER INT-EXT switch to INT. For units without internal sampling, obtain leveled operation with an external sampler as described in item 5a above.

c. Connect the RF OUTPUT jack through a suitable attenuator to a crystal detector, and connect the detector output to the vertical channel of an oscilloscope. Use the OUTPUT SWEEP signal to drive the horizontal channel of the oscilloscope.

d. Rotate the POWER LEVEL control slightly away from the CCW position and then back to the CCW position, and observe the oscilloscope trace level which should move up and down to indicate that the output level is tracking the setting of the POWER LEVEL control. (If this response is not obtained, turn the CONTROL VOLTAGE LIMIT adjustment A11R42 in the CW direction to permit such response).

e. While continuing to rotate the POWER LEVEL control as in step d, turn the CONTROL VOLTAGE LIMIT adjustment A11R42 CCW slowly until it interferes with smooth tracking, by the oscilloscope trace, of the POWER LEVEL control. When the point of interference is reached, back off the CONTROL VOLTAGE LIMIT adjustment in the CW direction about 3 degrees.

f. Turn the MODULATION Mode Selector to SQ WAVE.

g. Observe the character of the square wave pulses and make a slight "touch-up" adjustment of the CONTROL VOLTAGE LIMIT adjustment A11R42 over a range of $\pm 3^{\circ}$ to improve pulse rise time (ccw adjustment) and limit overshoot (cw adjustment) if necessary.

7. A11R1 LEVELER BALANCE Adjustment (only on grid-leveled instruments 64(*)0, 64(*)1, and 64(*)4). This adjustment is used to balance the base-emitter voltages of the input dual transistor A11Q1. These voltages do not change with age. Unless the factory adjustment is altered improperly, readjustment should be required only when A11Q1 is replaced. At that time, A11R1 should be carefully set to provide a proper balance between the extremes of (1) keeping the UNLEVELED light on improperly when the output is leveled, and (2) obtaining overshoot in the leveled response, particularly at the rf turn-on step function after retrace blanking or during square wave modulation.

To adjust the LEVELER BALANCE, proceed as follows:

a. Make the following control settings:

FREQUENCY Mode Selector to OFF.
MODULATION Mode Selector to AM OFF.
RF OUTPUT to LEVELED.
(Black POWER LEVEL control, Red POWER LEVEL control and RF SAMPLER INT-EXT switch, where present, can be at any position).

b. Adjust the LEVELER BALANCE control A11R1 until the UNLEVELED light just goes out.

c. Connect the RF OUTPUT jack through a suitable attenuator to a detector, and connect the detector output to the vertical channel of an oscilloscope (see Figure 5-5). Use a 47-ohm resistor to terminate the detector cable at the oscilloscope to provide a proper load for the crystal. Use the OUTPUT SWEEP signal to drive the oscilloscope horizontal channel.

NOTE: On units without internal sampling, connect an external sampler or a directional coupler and detector to drive the SAMPLER INPUT jack. This sampler or coupler should be connected between the RF OUTPUT jack and the attenuator/detector described in Step c above.

d. Make the following changes in control settings:

FREQUENCY Mode Selector to SINGLE
SINGLE Frequency Selector to F_0
MODULATION Mode Selector to SQ WAVE
RF SAMPLER switch to INT (if applicable)
Red POWER LEVEL control to mid-range
Black POWER LEVEL control* (if present) fully CW

e. Examine the CRT presentation for excess overshoot on the "rf on" step. Adjust the LEVELER BALANCE control A11R1 slightly, just enough to eliminate any overshoot.

NOTE: If too much adjustment is made, the square-wave symmetry may be degraded.

f. Turn the F_0 control to manually sweep the output signal frequency across the band while examining the leveled square wave trace on the CRT for absence of overshoot or poor symmetry. Make a slight re-adjustment of the LEVELER BALANCE control A11R1 if necessary.

g. Leaving the black POWER LEVEL control* fully CW, turn the red POWER LEVEL control CCW to reduce the output level over a 5-db range below the full-band-leveled point. Again examine the leveled square wave trace on the CRT for absence of ov-

*Only on instruments having flap attenuator.

ershoot or poor symmetry. Make a slight re-adjustment of the LEVELER BALANCE control A11R1 if necessary.

5.3.5 FREQUENCY CALIBRATION ADJUSTMENT. (See Figure 5-5.)

The following procedure should be used for periodic frequency calibration.

CAUTION

Check all supply voltages except the cathode supply output before performing this calibration adjustment. (See Paragraph 5.2.)

a. Let the instrument warm up and stabilize for about 1/2 hour.

b. Make the following control settings:

RF OUTPUT to UNLEVELED
FREQUENCY Mode Selector to SINGLE
SINGLE Frequency Selector to F_0
MARKER AMPLITUDE to OFF
MODULATION to AM OFF
SWEEP TIME to .01
SWEEP TRIGGER to FREE RUN

c. With the instrument operating unmodulated in single-frequency mode, measure the cathode supply voltage output at the lower and upper band limit frequencies as directed in Paragraph 5.2.3 a.

d. If either voltage measured in Step c is incorrect, adjust it to the proper value using the START FREQ or END FREQ adjustment controls. (The START FREQ adjustment sets the voltage at the low band-edge frequency, and the END FREQ adjustment sets the high band-edge frequency.)

e. Connect an rf test loop consisting of a variable attenuator, wavemeter, and crystal detector to the RF OUTPUT jack, and connect the crystal detector output to the vertical channel input of an oscilloscope. Use the OUTPUT SWEEP signal to drive the horizontal channel of the oscilloscope.

f. Make the following changes in control settings:

FREQUENCY Mode Selector to SWEEP $F_0 \pm \Delta F$
RETRACE to OFF
ΔF AMPLITUDE fully CW
SWEEP TIME to .01
SWEEP TRIGGER to FREE RUN
F_0 to 0 on the logging scale (the low band-edge frequency).

g. Adjust the wavemeter to the low band-edge dial frequency.

h. Observe the CRT presentation. The wavemeter pip should appear exactly in the center of the trace. If it is obviously off-center, adjust the A13R26 START FREQ control to move the pip to the center of the trace.

i. When the pip appears centered in Step h above, turn the ΔF AMPLITUDE control CCW slowly, continuing to the CCW rotation limit (labeled 0) unless the pip appears off center as the control is turned. If necessary, stop turning the ΔF AMPLITUDE control, and adjust the START FREQ control again to restore the pip to the center of the trace. Continue this procedure until the ΔF AMPLITUDE control is fully CCW and the wavemeter pip remains in the center of the trace.

j. Adjust the wavemeter to the high band-edge dial frequency.

k. Adjust the F_0 FREQUENCY control to 100 on the logging scale, and turn the ΔF AMPLITUDE control fully CW.

l. Observe the CRT presentation. The wavemeter pip should appear exactly in the center of the trace. If it is obviously off-center, adjust the A13R28 END FREQ control to move the pip to the center of the trace.

m. When the pip appears centered in Step l above, turn the ΔF AMPLITUDE control CCW slowly, continuing to the CCW rotation limit (labeled 0) unless the pip appears off center as the control is turned. If necessary, stop turning the ΔF AMPLITUDE control, and adjust the END FREQ control again, to restore the pip to the center of the trace. Continue this procedure until the ΔF AMPLITUDE control is fully CCW and the wavemeter pip remains in the center of the trace.

n. Adjust the F_0 FREQUENCY control to 0 on the logging scale and turn the ΔF AMPLITUDE control fully CW.

o. Repeat Steps g through m.

p. Repeat Steps n and o one additional time. Repeating the steps is necessary because of the interaction of the START FREQ adjustment A13R26 and END FREQ adjustment A13R28.

q. Check the frequency tracking across the dial at several points by turning the ΔF AMPLITUDE control to 100% and setting both the F_0 control and the wavemeter to identical frequencies. Frequency accuracy should be $\pm$ 1.0% or better across the band. If necessary, Steps n through p above may be repeated to offset the end frequencies slightly in order to reduce mid-band inaccuracies.

r. If it is desired to check residual FM and AM, retain the test set-up and follow the procedures of Paragraph 5.3.6.

5.3.6. CHECKOUT PROCEDURE FOR RESIDUAL FM AND AM. (See Figure 5-5.)

The following procedure may be used for periodic verification that residual FM and AM are within specification limits. It should be performed as a continuation of the frequency calibration adjustment procedure given in Paragraph 5.3.5 above. The FM procedure should be performed at the low-frequency end of the band, because residual FM effects are greatest at that point; and the AM procedure should be performed at the high-frequency end of the band.

a. The instrument should be operating with an rf test loop equivalent to Step e of Paragraph 5.3.5. To permit the high sensitivity readings required later in the procedure, the oscilloscope should be set for AC coupling.

b. Make control settings as in Step f of Paragraph 5.3.5, except turn the RETRACE control to ON. Also set the RF OUTPUT control to UNLEVELED and turn the MARKER AMPLITUDE and MODULATION both off.

c. Adjust the wavemeter to center its pip on the CRT display.

d. Slowly turn the ΔF AMPLITUDE control CCW, while adjusting the wavemeter slightly, as necessary to keep the

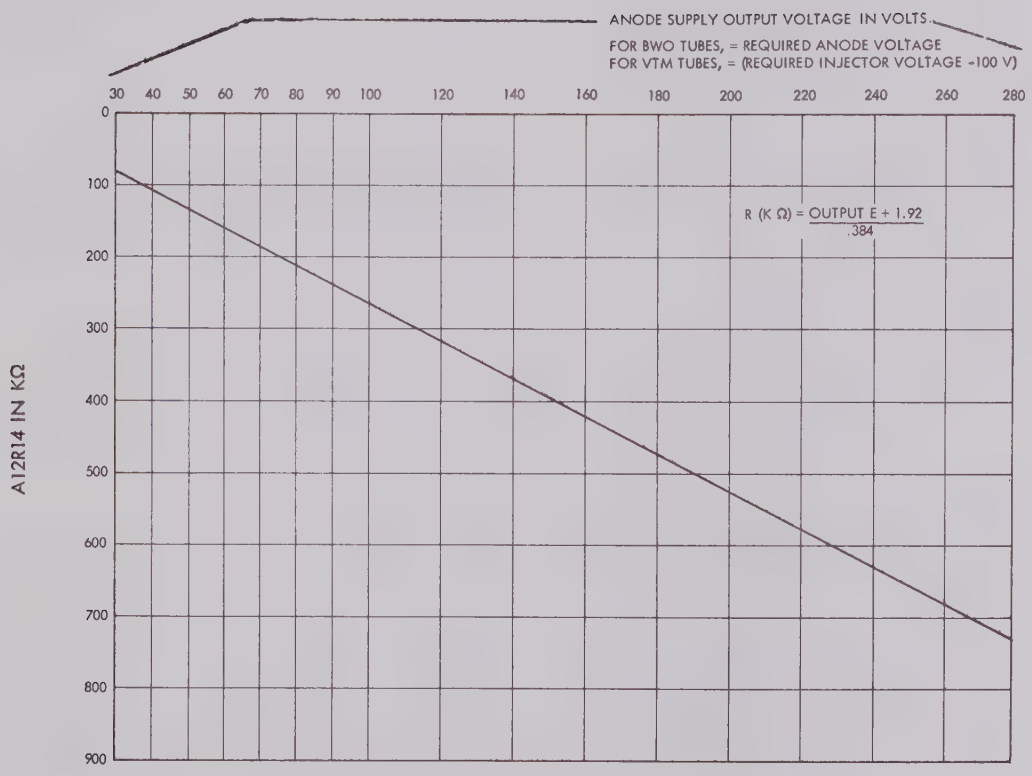


FIGURE 5-4. GRAPH OF ANODE FEEDBACK RESISTOR VALUES VS REQUIRED ANODE SUPPLY OUTPUT VOLTAGE FOR PLUG-IN UNITS

wavemeter pip centered on the CRT trace. Continue this procedure until the Δ F AMPLITUDE control is fully CCW.

e. Set the wavemeter to place one-half of its pip at the left edge of the trace.

f. Adjust the oscilloscope horizontal sensitivity to yield a full-graticule sweep width while being driven by the OUTPUT SWEEP signal of the Model 6400.

g. Adjust the oscilloscope for maximum vertical sensitivity, and set the vertical position so that the CRT presentation shows a sloping line which represents one half of the magnified wavemeter pip at the left edge.

h. Adjust the wavemeter enough to move the sloping line (pip) from one edge of the CRT presentation to the other. The difference between the wavemeter settings at each edge of the CRT will calibrate the horizontal scale (typical value = 20 MHz).

NOTE: Since the rf output is being left on during retrace, there will be two parallel lines visible on the CRT. Use the brighter line for the residual FM check (the dim line is the retrace indication).

i. Adjust the wavemeter slightly to move the sloping line to a convenient point on the graticule.

j. Observe the horizontal jitter in the line while the Δ F AMPLITUDE control remains fully CCW. The horizontal scale calibration made in Step h above will permit evaluating the frequency deviation of the jitter.

This deviation should be less than ± the KHz value indicated for "Maximum Residual FM" in Table 1-1. If excess residual FM is present, check the ripple voltage on the cathode supply [TP6 (-), TP3 (+; chassis ground)] . Use an oscilloscope with a 10:1 divider probe and operate the vertical channel with ac coupling. The ripple voltage should not exceed ± 0.01% of the cathode supply output voltage at any point. Refer to the trouble-shooting procedures for the cathode supply if excess ripple is present. If excess power supply ripple is not present, the excess re residual FM may be due to arcing or other breakdown in the BWO tube, which requires replacement of the tube.

NOTE: If desired, the above residual FM checkout procedure may be repeated at other frequencies in the frequency range of the plug-in unit. Since arcing or other breakdown effects in a BWO tube often show up initially as excess residual FM, this procedure can be useful in evaluating performance of aging BWO tubes.

k. Make the following changes in control setting, in preparation for the residual AM test.

FREQUENCY Mode Selector to SINGLE
SINGLE Frequency Control to F_0
F_0 control set at high end of band
MODULATION to SQUARE WAVE

l. Adjust the wavemeter away from the frequency of interest, or remove it from the circuit completely, as desired. Make sure that sufficient attenuation is provided in the rf test loop to allow the crystal detector to operate in its square-law range.

m. Adjust the oscilloscope for a free-running horizontal sweep independent of the Model 6400. Leave the oscilloscope vertical input ac-coupled. Adjust the oscilloscope vertical sensitivity to obtain a square-wave height of 5 scale divisions (5 cm) on the graticule.

n. Turn the MODULATION switch to AM OFF.

o. Without changing the vertical sensitivity vernier adjustment of the oscilloscope from the setting used to obtain a full-height display in Step m, set the oscilloscope vertical sensitivity switch to step-increase vertical amplification by a factor of 10 (so that the full-height square-wave presentation would now be 50 scale divisions). Adjust the zero position control as necessary to place the unmodulated power-on straight line trace at a convenient line on the graticule.

p. Observe the vertical ripple on the CRT trace. It must not exceed 1 scale division (i.e. less than 1/50 or 2% of the output amplitude). If excess residual AM is present, refer to the trouble-shooting procedures for the anode and -100 V supplies.

5.4 TROUBLE SHOOTING.

5.4.1 STEPS TO FOLLOW WHEN FAILURE OCCURS. First check all voltages in accordance with Paragraph 5.2 to help localize the trouble to a low voltage supply or other low voltage control circuit, or to the microwave tube or a high voltage supply/tube bias circuit.

CAUTION

If trouble is localized to the heater supply, temporarily disconnect the microwave tube connections in accordance with the diagrams given under Paragraph 5.7 to avoid applying improper voltages to the tube while operating the Model 6400 to localize trouble to particular components.

After making voltage measurements, refer to the appropriate one of the trouble-shooting tables for individual supplies, if outputs are incorrect. If supplies are functioning properly, refer to the general trouble-shooting table, Figure 5-2, for assistance in locating the failed circuit and components. Before proceeding further, read the additional troubleshooting hints and cautions in the following paragraphs.

5.4.2 USE OF THE TROUBLE-SHOOTING TABLES. Tables 5-2 through 5-11 provide basic trouble shooting information for any Model 6400 instrument. Table 5-2 is a general procedure which localizes gross performance faults to a particular circuit section. Tables 5-3 through 5-11 will be helpful to localize both failures and minor faults in individual power supplies and circuits.

5.4.3 VOLTAGE AND WAVEFORM MEASUREMENTS. Voltage and waveform measurements are indicated on the simplified schematics of the Model 6400 circuits in Figures 4-2 through 4-16 and 4-23 and on the apron of schematic 900933 in Section 7. These measurements can be used for trouble shooting within the circuits referenced by the trouble shooting tables. Conditions of measurement are indicated on each schematic. Keep in mind that the voltage and waveform measurements shown are typical, intended for use in localizing trouble in faulty circuits. Even where several significant digits are shown on these "typical" measurements, they do not imply "standard" values, but instead are intended to give a better picture of the relative interstage levels in the circuit. Normal component variations can produce voltage variations commensurate with the component tolerances used in any particular circuit.

CAUTION

All measurements should be made with respect to chassis ground, unless otherwise indicated on the simplified schematics. In conjunction with measurements on the cathode supply (Figure 4-7), note that because of mechanical limitations in the dial mechanism, the instrument is factory-calibrated to produce the full frequency output range in response to a panel control potentiometer output range of approximately 0.15 V to 14.75 V. These voltages correspond to the 0-scale and full-scale dial settings. Do not attempt to change the calibration of these controls.

WARNING

All waveform and voltage measurements are made with high voltage off unless otherwise noted. Exercise extreme caution when checking high voltage circuits.

5.4.4 LOCALIZATION OF TROUBLE TO INDIVIDUAL COMPONENTS. In addition to making voltage and waveform measurements, it may be necessary to perform some active or passive circuit testing to pinpoint the defective component(s). In most cases, the performance of a particular transistor that is forward-biased can be evaluated by shorting the emitter and base lead where circuit voltages permit, or by opening the base lead. In either case, the transistor will be turned off unless it is shorted. Resultant changes in circuit voltages can be monitored to determine whether the transistor is performing. If a transistor does not conduct when its v_{be} exceeds cutoff - as can be determined by in-circuit measurements of its lead voltages (this may require base-emitter shorting or base opening on other transistors to establish proper conditions) - it can be assumed to be open.

NOTE: The tab on all single transistors identifies the emitter lead. The tab on all dual transistors identifies the collector leads.

Another method of locating open or shorted transistors is by means of resistance measurements across the elements. Because of differences in transistors and ohmmeters, no specific information can be given about exact resistances. Generally, the ratio of forward and backward emitter-collector resistance is between 10:1 and 100:1, the ratio being lower for the higher-powered transistors. When a defective transistor is located, always look for another faulty element in the circuit which may have contributed to or resulted from the transistor failure.

Resistors and capacitors should be checked with one lead unsoldered to avoid any possibility of shunt paths and/or damage to transistors and diodes. Tubes A10V1 through A10V3 and A10V4 and A10V5 are best checked by substitution. A10V1 through A10-V3 in the cathode supply should be replaced together.

CAUTION

1. USE OF OHMMETER. If an ohmmeter is used to check the forward and reverse resistance of transistors, or to make in-circuit resistance measurements in transistor circuits, check the ohmmeter voltage and current output on the range to be used before making any measurements. Many ohmmeters are unsuitable for use on certain ranges because they supply enough voltage or current to damage a transistor. Check both the open-circuit voltage and the short-circuit current, using suitable test instruments. Do not use any range where open-circuit voltage exceeds 1.5 V or short-circuit current exceeds 3 ma, because these levels may damage transistors.

2. MEASURING TRANSISTOR VOLTAGES. When checking to determine whether a particular transistor is forward-biased, measure the voltage on each lead independently with respect to ground. Do not attempt to measure v_{be} in one step by attaching the voltmeter directly to both leads, because transistor-damaging auxiliary currents may be established.

3. REMOVAL OF PC BOARDS. When a PC board extender is used for convenient access to one of the plug-in PC boards on the right-hand side of the Model 6400 to allow making test measurements, or if a PC board is removed for component checking, observe the following precautions:

   a. Always turn the POWER switch OFF before disconnecting or connecting any PC board, either directly to its receptacle or through the board extender. If this is not done, there is the possibility that some transistors will be burned out by transients that take place when the connection is made or broken.

   b. While the board extender may be turned 180° as necessary to fit the keyed receptacles, the PC board being extended must always be kept in its normal orientation, i. e., with the components on the side toward the instrument front panel. If the PC board is inadvertently turned 180° extensive circuit damage may occur because of improper connections.

5.4.5 USE OF THEORY OF OPERATION. The detailed circuit theory given in Section 4 will be helpful in locating possible causes of trouble. A good understanding of the circuit theory will enable a technician to analyze a particular indication of trouble in terms of possible faulty circuits or components to be checked out.

5.4.6 BWO TUBE AGING AND FAILURE. There are three general indications of BWO tube aging: (1) reduced rf output throughout the operating band; (2) complete loss of rf output at one or more frequencies in the operating band; (3) repeated tripout of the helix overcurrent protection relay when operating unleveled with full output power, particularly in the upper portion of the operating band. Indications (1) and (2) above are usually caused by reduced cathode emission, while gas ionization in the BWO tube causes indication (3). Indication (2) at either band limit can be caused by a defective cathode supply or a defective or mis-adjusted diode shaper board that produces cathode voltage outside the proper tuning range. Normal aging of the BWO tube does not produce frequency calibration error; but internal arcing or other breakdown can produce excess residual fm.

To localize trouble to the BWO tube when indications of the above type are present, check all tube voltages and currents in accordance with Paragraph 5.2 above, and make adjustments as necessary following the procedures of Paragraph 5.3. If proper operation is not restored with proper voltages applied, and the BWO tube is still in warranty, read the Tube Warranty and Replacement Procedure at the rear of this manual and follow the specified return procedure. If the tube warranty has expired, refer to the procedure of Paragraph 5.3.4, Item (1), and try increasing the anode voltage above the normal level to resotre power output, before discarding the tube.

NOTE: Where failure is due to gas ionization, no adjustment of voltages will restore normal, full-band operation. If desired,

the tube can still be used within a restricted tuning range, at frequencies below the point where excessive helix current occurs.

5.4.7 ELEVATED SUPPLY FAILURE. When failure is suspected in the Elevated Supply PC Board A12, all the passive components can be checked with power turned off. If the passive components are satisfactory, and the correct grid voltage is not produced with suitable drive from the modulator, check the performance of A12Q1 by substitution.

5.4.8 DIODE SHAPER BOARD FAILURE. If the proper voltages cannot be obtained when adjusting the START FREQ and END FREQ adjustment controls, and voltage measurements on the cathode supply feedback amplifier indicate that it is operating properly, check the performance of the diode shaper board. Typical operating voltages on the resistor biasing string are indicated in Figure 4-22. Performance of the diodes can be checked with power off by using an ohmmeter to measure forward and reverse resistance. To avoid overloads, do not use any range where open-circuit voltage exceeds 1.5 V, or short-circuit current exceeds 3 ma. In-circuit voltage checks may also be used to check A13Q1, A13Q2, A13CR13 and A13CR14.

5.4.9 INTERNAL SAMPLER FAILURE. If the instrument operates properly with an external sampler known to be in good condition, but performance with internal sampling is unsatisfactory, check the adjustment of the INTERNAL SAMPLER SENSITIVITY control following the procedure of paragraph 5.3.2. Also check the crystal detector on the internal sampler by substitution. If the internal sampler or its crystal detector are replaced, reset the INTERNAL SAMPLER SENSITIVITY adjustment following the procedure of Paragraph 5.3.4.

5.4.10 LEVELER-AMPLIFIER IMBALANCE or FAILURE.

5.4.10.1 PIN-Leveled Units (Models 64(*)2, 64(*)3, and 64(*)5): When the CONTROL VOLTAGE LIMIT adjustment is not set properly, it can interfere with the normal smooth leveler response by unbalancing the feedback loop. When response does not seem consistent across the full swept band or at low and high power levels, re-adjust the CONTROL VOLTAGE LIMIT as directed in Paragraph 5.3.4. If the CONTROL VOLTAGE LIMIT adjustment cannot restore proper operation, make voltage measurements in the leveler-amplifier under various operating conditions, in accordance with the table shown on schematic D900933. These measurements should localize the trouble to the defective component or stage - or to the PIN diode attenuator module itself.

5.4.10.2 Grid-Leveled Units (Models 64(*)0, 64(*)1, and 64(*)4): When the LEVELER BALANCE adjustment is not set properly, the UNLEVELED light will not faithfully track the occurrence of fully leveled response over the band being swept. The light may stay on continually, or it may work OK with internal leveling but not on external leveling. An improper balance adjustment in the opposite direction can also produce excess overshoot on the rf trace turn-on at the end of the "retrace off" interval, and a lesser overshoot on individual cycles of square-wave modulation. When any of these indications occur, re-adjust the LEVELER BALANCE control as directed in Paragraph 5.3.4. If the LEVELER BALANCE adjustment cannot restore proper operation, make voltage measurements in the leveler-amplifier circuit under operating conditions, as indicated in Figure 4-23, to locate the defective component or to localize the trouble to the transfer oscillator or elevated supply.

After replacement of the BWO tube it may be necessary to change the values of starred components indicated on the schematic diagram and on Figure 4-23. If oscillatory amplitude variations occur in leveled operation, the capacitance value of A11C3 must be increased, and the value of A11R6 must be reduced so that the R-C product of A11R6 x A11C3 remains constant.

If the leveler response exhibits slow-rise characteristics, it may be necessary to reduce the capacitance value of A11C3. In that event, also increase A11R6 so that the product of A11C3 x A11R6 remains constant. The value of A11C3 must not be reduced enough to cause oscillatory leveler operation.

NOTE: The allowable adjustment range of A11C3 is 0.1 to 0.0005 µf (.022 µf nominal).

5.4.11 PIN ATTENUATOR MODULE FAILURE. (Models 64(*)2, 65(*)3, and 64(*)5 only): If the output is not leveled, and does not change in response to adjustment of the POWER LEVEL control, and if voltage checks on the leveler-amplifier (para. 5.4.10.1) indicate that a proper drive is being supplied at terminal A11-15, the PIN attenuator may be defective. To check the PIN attenuator, perform the following procedure:

a. First check that proper -12 V power is being supplied to the leveler from the PIN attenuator power supply $A11_{ps}$. Measure this voltage between pin 1 of the PIN attenuator module (-) and the module body (+, ground) with a digital voltmeter.

b. If the voltage monitored in step a is not within the specification range of -12 ± 0.1 V, adjust it using $A11_{ps}R6$.

c. Monitor the supply ripple by connecting an oscilloscope to the same terminals [pin 1 of the leveler module (-) and the module body (+, ground)]. Ripple should be < 5 mv.

d. If the voltage cannot be properly adjusted or has excessive ripple, check the power supply components for failure and replace as necessary. Then check and adjust the voltage in accordance with steps a and b above.

e. To check the PIN attenuator, the 0.5 V to -2.0 V control range provided at A11-15 in the unleveled mode (as verified by the measurements of paragraph 5.4.10.1) will be used to provide full-range drive to the leveler module for this test.

f. Make control settings as follows:

RF OUTPUT to UNLEVELED
FREQUENCY Mode Selector to SINGLE
SINGLE Mode Selector to F_0
F_0 control to band center
RETRACE to OFF
MARKER AMPLITUDE to OFF

g. Connect the RF OUTPUT connector to an rf power measurement loop such as shown in Figure 5-6.

h. Monitor the power output range provided when the POWER LEVEL control is adjusted over its full range from the CCW limit to the CW limit. The difference between minimum and maximum output should be as follows:

Freq. Range of Instrument (GHz)	PIN Attenuator Part No.	Min. Difference Between Min. & Max. Output	
1-2	951041-02	25.5 db	Unleveled Mode
1.7-4.2	951041-02 or -03	30.5 db	
3.5-8.3	951041-04	26.5 db	
7-12.4	951041-05	22 db	

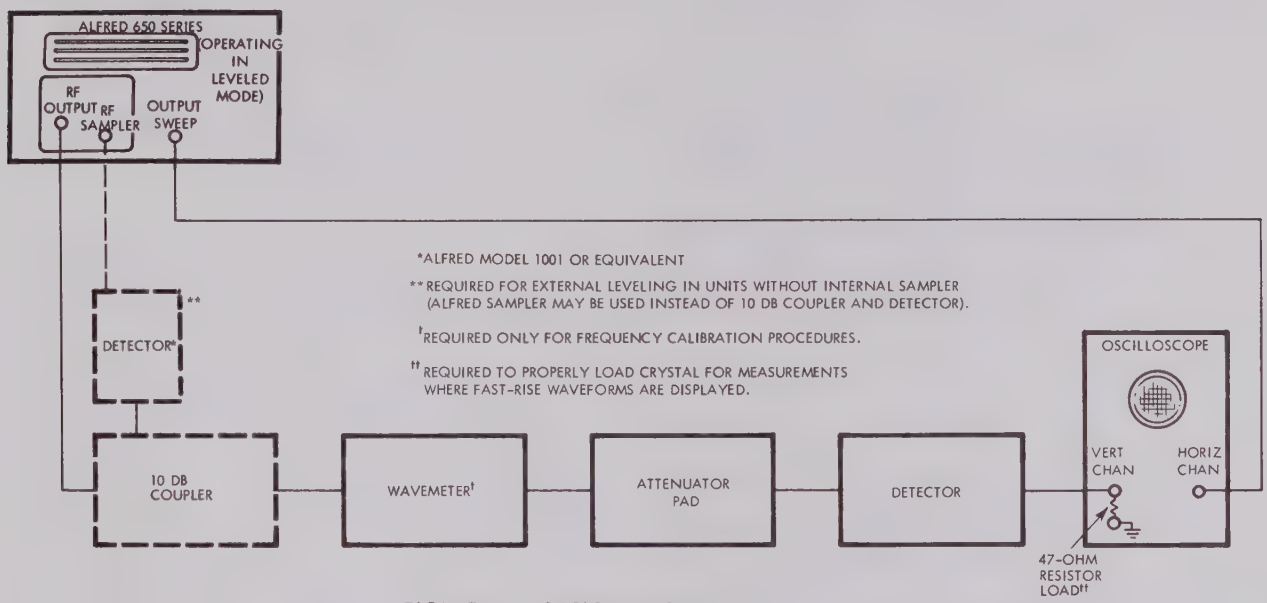

ALFRED 650 SERIES
(OPERATING IN LEVELED MODE)
RF OUTPUT
RF SAMPLER
OUTPUT SWEEP
*ALFRED MODEL 1001 OR EQUIVALENT
** REQUIRED FOR EXTERNAL LEVELING IN UNITS WITHOUT INTERNAL SAMPLER (ALFRED SAMPLER MAY BE USED INSTEAD OF 10 DB COUPLER AND DETECTOR).
† REQUIRED ONLY FOR FREQUENCY CALIBRATION PROCEDURES.
†† REQUIRED TO PROPERLY LOAD CRYSTAL FOR MEASUREMENTS WHERE FAST-RISE WAVEFORMS ARE DISPLAYED.
DETECTOR*
**
10 DB COUPLER
WAVEMETER†
ATTENUATOR PAD
DETECTOR
OSCILLOSCOPE
VERT CHAN
HORIZ CHAN
47-OHM RESISTOR LOAD††

FIGURE 5-5. BASIC RF TEST SET-UP

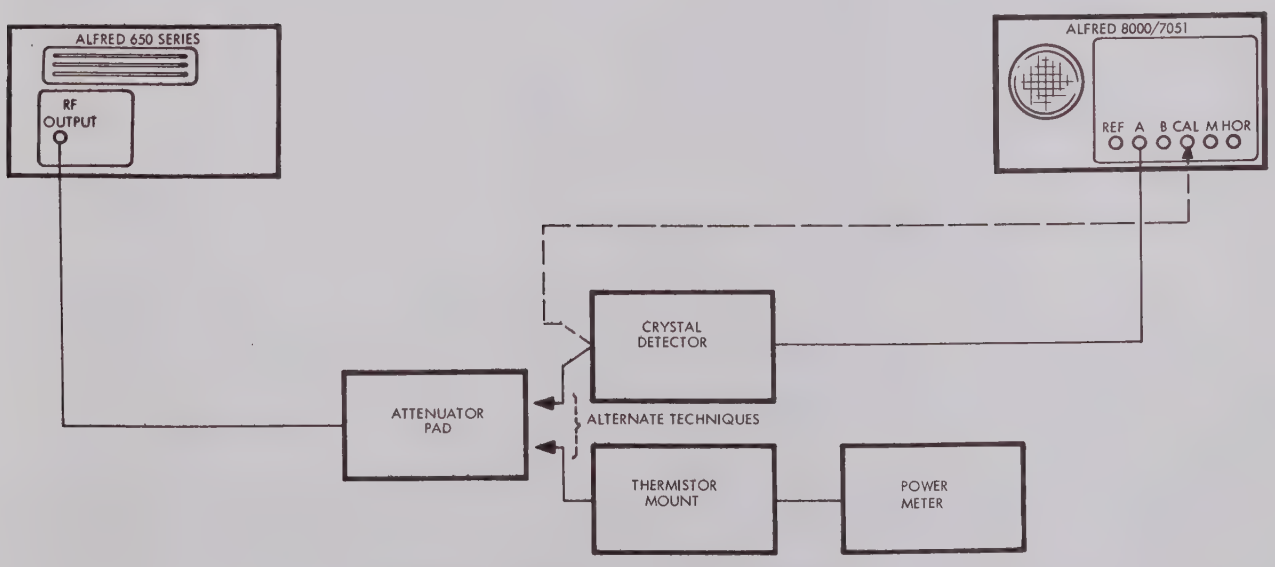


FIGURE 5-6. POWER CALIBRATION TEST SET-UP

i. Adjust the F_0 control to each band limit and repeat the power control range test of step h. If adequate control range is provided across the band, the PIN attenuator module is probably operating properly. If no or insufficient control range is provided, the PIN attenuator module is probably defective and must be returned to the factory for repair.

CAUTION

The PIN diode attenuator module is not field repairable or field adjustable. Do not attempt to adjust or disassemble the attenuator or driver circuits in the field.

j. A final check of PIN attenuator performance can be made by removing the PIN attenuator module from the instrument. Label the wires attached to pins 1, 7, 8, and the body, and then unsolder them. Then remove the leveler attaching hardware and disconnect the rf lines.

k. To supply -12 V power to the PIN attenuator for external testing, connect jumpers as follows:

Pin 1 of the PIN attenuator power supply to the attenuator module body.
Pin 6 of the PIN attenuator power supply to pin 1 of the attenuator module.
Turn on instrument power to apply 115 VAC to pins 4 and 5 of the PIN attenuator power supply.

l. Obtain a controlled, well regulated and filtered dc test source with an output in the range 0.5 - 2.0 Vdc.

m. Adjust the dc test source voltage to 0.5 V, and connect its + lead to the PIN attenuator module body (ground) and its - lead to pin 7 of the PIN attenuator module.

n. Connect the PIN diode attenuator into an rf power measurement loop such as shown in Figure 5-6, between the signal source attenuator and the detector. The source output and attenuator value should be selected to avoid applying more than 100 mw to the PIN attenuator.

o. Set the dc test source voltage (with polarity as specified in step m) first to 0.5 V and then to 2.0 V, and monitor the output level in each case. The leveler should provide minimum attenuation at a control voltage of 0.5 V, and maximum attenuation at a control voltage of 2.0 V. Attenuation provided in each case should be:

FREQ. RANGE OF PLUG-IN UNIT (GHz)	PIN ATTENUATOR PART No.	MIN. ATTENUATION	MAX. ATTENUATION
1 - 2	951041-02	≦2.5 db	≧28.0 db
≦1.7 - 4.2	951041-02 or -03	≦2.5 db	≧33.0 db
≦3.5 - 8.3	951041-04	≦3.5 db	≧30.0 db
≦ 7 - 12.4	951041-05	≦5.0 db	≧27.0 db

If attenuator is outside these limits, the attenuator must be returned to the factory for repair.

p. To measure PIN attenuator input matching, terminate the output connector in a 50 Ω load and connect a directional coupler to the input connector, oriented to pick up reflections from the PIN attenuator. Connect the detector to the coupler arm to measure the return loss using reflectometry techniques. Return loss with leveler control voltage anywhere in the 0.5 - 2.0 V range should be more than the above minimum.

FREQ. RANGE OF PLUG-IN UNIT (GHz)	PIN ATTENUATOR PART No.	MIN. RETURN LOSS (EITHER END)
1 - 2	951041-02	8.0 db
≦1.7 - 4.2	951041-02 or -03	9.0 db
≦3.5 - 8.3	951041-04	7.5 db
≦ 7 - 12.4	951041-05	6.5 db

q. Interchange the rf test connections to the PIN attenuator input and output connectors and repeat the return loss measurement of step p above. If return loss is less than the minimum specified at either end, the PIN attenuator must be returned to the factory for repair.

5.4.12 FAILURE OR MISADJUSTMENT OF ANODE PROTECTION CIRCUIT. (Units with Varian tubes only). The anode protection circuit is inherently reliable and is factory adjusted to trip out when the maximum allowable anode current is reached for the particular tube type used in the instrument. This factory adjustment should rarely if ever, require re-setting, since the circuit components are stable with time, and all replacement tubes of the same type require the same setting. If repeated trip-outs are traced to the anode protection circuitry the circuit can be checked and calibrated using the following procedure:

a. With the Model 6400 POWER switch turned OFF, connect a variable power supply between terminal #1 (+) and #2 (-) of the 951155 Anode Protection Circuit (see Figure 5-1 for location). The power supply must be current limited or protected, since the circuit will draw 250 ma when tripped.

b. Connect a variable 10K resistor (set to maximum resistance) and a D.C. milliameter in series, between terminal #2 and #3 of the Anode Protection Circuit.

c. Set Anode Current Adjust calibration potentiometer A19R2 fully CW, and apply 50 volts between terminal #1 and #2 with the variable power supply.

d. Adjust the variable 10K resistor until the milliammeter reads one milliamp less than the maximum anode current shown for the specific Varian BWO tube type, in Table 5-12. (e.g. BWO Tube Type VA160A would required an adjustment to obtain anode current of 10 ma.)

e. Now calibrate the Anode Protection Circuit by rotating calibration potentiometer A19R2 CCW until trip occurs. A trip condition is indicated when current out of the power supply rises sharply. The Anode Protection Circuit is now calibrated. If the Anode Protection Circuit cannot be properly calibrated to the specified trip-out current level, it is defective and a replacement Anode Protection PC board should be obtained from the factory.

f. Disconnect the variable power supply, the 10K variable resistor, and the milliameter from the Anode Protection Circuit.

Table 5-2. Trouble-Shooting Chart for the Model 6400

Trouble (Indication)	Probable Cause	Remedy
1. NO PRIMARY POWER (POWER ON light does not come on when POWER switch is turned ON.) See Figure 4-2.	a. Main fuse F2 blown.	a. Check the primary control circuits for a short or a faulty component. Check RT1, S1, S2, S3, K2 and K3.
	b. Low voltage fuse F1 blown (accessible from chassis bottom, Figure 5-4).	b. Check for a short on the primary side of T1. (This is best done with the L. V. supply PC board A2 removed, to reduce the load on T1. Check for shorts in the low voltage rectifier circuit wiring on the secondary side of T1 (see Schematic 900845). Check for a short on board A2. (See Figures 4-3 through 4-6.)
2. NO HIGH VOLTAGE POWER (HIGH VOLTAGE ON light does not come on after the primary power has been on for about 60 seconds.) See Figure 4-2.	a. Top or rear panel interlock switch tripped.	a. Check that top cover and silkscreened rear panel are properly installed.
	b. High voltage fuse F3 blown (accessible from chassis bottom, Figure 5-4).	b. Check the high voltage control circuit for a short or faulty component. Check S3, S5, S6 and the primary of T2. Check the cathode, anode and the -100 V supplies for shorts. See Figures 4-7, 4-8, 4-11, and 4-12.
	c. Low voltage supply failure.	c. Check the low voltage supply outputs for proper voltages. (See Paragraph 5.2 and Table 5-1. The +100 V is used to actuate high voltage control relay K2. Refer to Table 5-3 to localize trouble in any supply which has improper output.
	d. Heater overvoltage.	d. With the primary power on check to see that light A6DS2 is not on. A6DS2 is on PC board A6, Figure 5-1. If the light is on, check the heater supply adjustment (Paragraph 5.3). (Also see Table 5-6.)
	e. Helix overcurrent relay tripped.	e. With the primary power on check to see that relay A7K1 is energized. (A7K1 is on PC board A7 behind the front panel, Figure 5-1.) When the top cover is removed for access to A7K1, it will be necessary to manually actuate the top interlock switch to determine whether A7K1 remains energized, as it should, when high voltage is enabled. If A7K1 is not energized, check helix current as directed in Step 3. below. If the tube is drawing excessive helix current, it may have been defocused by being struck by a metallic screwdriver, and must be replaced. (See Paragraph 5.7.) See Table 5-5 below if trip-out occurs without excess current. Press the panel RESET button to restore power after the one-minute time delay, when the overload has been removed.
3. NO RF POWER OUTPUT (POWER ON and HIGH VOLTAGE ON lights are on, and no output signal is generated when controls are set for rf power output.) See Figures 4-7 thru 4-12.	a. Improper setting of panel controls.	a. Check that MODULATION and SWEEP TRIGGER controls are not set to inhibit rf output.
	b. Failure of one of the supply voltages for the microwave tube.	b. Check all supply and microwave oscillator tube voltages following the procedure of Paragraph 5.2. Refer to the appropriate table to localize trouble in any supply which has improper output.
	c. Defective blanking Circuit.	c. If all tube voltages are correct except that the BWO grid is held at the tube "off" level, check the blanking circuit components on the sweep and modulator circuit boards. (See Tables 5-4 and 5-10.) Also check the circuit of transistor modulator A12Q1 in the Elevated Supply PC board.
	d. Failure of the microwave tube.	d. If proper voltages are being supplied to the tube, as measured at the test points listed in Table 5-1, the trouble is probably a defective microwave tube. To help localize the trouble to the tube, check the measurable electrode currents. These vary, depending upon the type of tube used. With Stewart BWO tubes, the helix and collector currents can be measured; with Varian BWO tubes, the helix current can be measured. Refer to paragraph 5.2.3 for the measurement procedure. If the tube is not generating output with proper voltages applied, it must be replaced. (See Paragraphs 5.4.6 and 5.7.)

Table 5-2. Trouble Shooting Chart for the Model 6400 (continued)

Trouble (Indication)	Probable Cause	Remedy
3. NO RF POWER OUTPUT (continued)	e. Failure of microwave component in rf output circuit (filter, sampler, or diode solid state leveler).	e. If tube currents indicate proper operation, check the rf power output directly at the tube output connection. If no output power is supplied by the tube, replace it. If output is supplied, make progressive checks to locate the faulty component.
4. RF OUTPUT FREQUENCY WILL NOT SWEEP. (Instrument operates properly at any single frequency, but will not supply swept output.)	a. Failure of sweep circuit. b. Failure of sweep input impedance converter circuit in cathode supply.	a. Check sweep generator and triggering circuits on Sweep PC board A5. (See Table 5-4.) b. Check circuit of A1Q11 and A1Q13.
5. RF OUTPUT FREQUENCY SWEEP IS NONLINEAR. (Instrument operates properly at any single frequency, but will not supply linear and/or full-band swept output.)	a. Failure of sweep circuit. b. Failure of sweep retrace discharge circuit.	a. Check sweep generator circuit on Sweep PC board A5. (See Table 5-4.) b. Check V5 and other circuit components. (See Table 5-9.)
6. RF OUTPUT FREQUENCY CONTROL IS ERRATIC IN SWEPT AND SINGLE-FREQUENCY MODES.	a. Failure of low-voltage supply. b. Failure of cathode supply.	a. Check low-voltage supply outputs for proper voltages. (See Paragraph 5.2.) Refer to Table 5-3 to localize trouble in any supply which has improper output. b. Check tracking of cathode supply output at TP6 against the proper values given in Addendum A, following the procedure of Paragraph 5.2. Refer to Table 5-9 below to localize trouble in the cathode supply.
7. RF POWER NOT LEVELED. (Swept output shows same variations as in unleveled condition when controls are set for leveled rf output.	a. Improper control settings. b. (If external leveling is being used), insufficient output from external sampler and/or detector. c. Defective leveler circuit component in plug-in unit.	a. Refer to Paragraph 3.12. b. Measure the detector output at the frequency where minimum unleveled power is generated, using a VTVM. Switch the Model 6400 to a single-frequency mode to avoid sweeping into a higher power point in the spectrum while making this check. Detector output must be at least -60 mv. If sufficient output is supplied, try turning the RF SAMPLER SENS control CCW to increase the sensitivity. CAUTION Use a non-metallic screwdriver. c. Refer to Paragraphs 5.4.8 through 5.4.11.
8. RF OUTPUT WILL NOT AMPLITUDE MODULATE. (Continuous, unmodulated output is supplied when controls are set for rf output and square wave modulation.) See Figure 4-16.	a. Failure of -100 V supply. b. Failure of square wave modulator. c. Failure of transfer oscillator. WARNING: HIGH VOLTAGE. d. Failure of A12Q1 modulator circuit in elevated supply. WARNING: HIGH VOLTAGE.	a. Check the output of this supply as directed in Paragraph 5.2. b. With an oscilloscope check input waveform to the transfer oscillator at C18 (Figure 5-1). Waveform should be a square wave with a peak-to-peak amplitude of +11 V. If improper signal is supplied, see Table 5-10. c. With an oscilloscope, using floating connections, check the output waveform of transfer oscillator [TP12 (+),TP11 (-)]. Waveform should be a square wave with a peak-to-peak amplitude of 5 V. If improper signal is supplied, see Table 5-11. d. Check the output waveform between TP10 (+) and A12TP3 (-). Use an oscilloscope with floating connections. The waveform should be a square wave with a peak-to-peak amplitude of either 25 or 61 V depending upon the tube. (Refer to Paragraph 5.2.3e for details.)

Table 5-2. Trouble Shooting Chart for the Model 6400 (continued)

Trouble (Indication)	Probable Cause	Remedy
8. RF OUTPUT WILL NOT AMPLITUDE MODULATE. (continued)	e. Failure of microwave tube grid shorted to cathode.	e. Check grid-to-cathode continuity with all power off. Replace tube if necessary.
	f. Failure of leveler.	f. Refer to Paragraphs 5.4.8 through 5.4.11.
9. EXCESSIVE RESIDUAL FM. (Residual FM does not decrease when operating condition is switched from untriggered sweep to single-frequency operation.)	Failure of ac impedance converter in input of cathode supply.	Check circuit of A1Q8 and A1Q9, and also A1CR2 and A1CR3.
10. RF NOT FULLY TURNED OFF WITH FREQUENCY SWITCH IN THE OFF POSITION. (FREQUENCY Mode Selector switch is OFF; rf output is still supplied.)	Follow the localization procedure of Step 8 above. In Item b., a signal of +11 V should be obtained in the "rf off" condition. In Item c., an output of 5 V should be supplied in the "rf off" condition. In Item d., maximum grid voltage should be obtained in the "rf off" condition.	
11. CALIBRATION CHANGES WHEN RETRACE RF IS TURNED OFF ON FAST SWEEPS. (Controls set for swept operation. Sweep is set faster than one second. RETRACE control is OFF; frequency performance as measured with a wavemeter is altered when the RETRACE switch is OFF, compared with that observed with the RETRACE switch ON.)	A small shift in calibration is customary with microwave tubes under such conditions. When using sweep times too fast for recorder readout, the RETRACE switch should be left ON unless a CRT baseline is needed.	

Table 5-3. Trouble Shooting the Low-Voltage Supplies

Trouble Indication	Suggested Cause and Remedy
1. -15 V output is 0, and +15 V output is about +2 V.	Short circuit in -50 V supply. Check -50 V supply output at TP5. If incorrect, check for a short in A2Q11, A2Q12 or associated components. If necessary remove the A2 board and check for an overload in the using circuits connected to J1-D.
2. -15 V and +15 V outputs are both 0.	a. Check wiring for defective connection to TP2 or TP4 jack, and repair as necessary. b. If TP2 shows short to ground with board A2 plugged in and no short with A2 removed, check Q3 on the main chassis for internal short or short through mounting screws to chassis.
3. Improper +15 V supply output, -15 V OK.	a. Open A2R12 (if +15 V has been shorted to ground). Check and replace as necessary. Also check Q3 on the main chassis. b. Check A2Q1 and A2R1 and replace as necessary.
4. Output of +15 V supply is about +26 V; -15 V has no line regulation.	Check Q3 on the main chassis and replace as necessary.
5. All L. V. Supply output voltages are OK except one.	Poor connection at J1. Check connection of A2 to J1, and condition of J1 socket and wiring.
6. -15 V and +15 V outputs are improper when input line voltage drops. (Regulation should be maintained to below 90 V.)	a. Check CR4, CR5, CR6, or CR7 on the A15 PC Board for open or leaky condition. Replace as necessary. b. Check Q1, Q3, and Q4 on the main chassis. Replace as necessary. c. Overload in decoupled +15 V line (denoted by "+15 V" on schematics). Check A9Q1, A9Q2, or A9Q3 and associated components in Transfer Oscillator PC board for short. CAUTION: High voltage should be turned off for this check. d. Check circuits using "+15 V" in Modulator PC board (see Table 5-10 and Figure 4-16).
7. Ripple in lumps on -15 V supply.	a. Check A2Q6, A2Q7, or A2Q8, and replace as necessary. b. Check Q4 on the main chassis and replace as necessary. c. Improper functioning of heater supply. Check the heater supply output between TP6 and TP7 to see that it is set at 6.3 V and is regulated. If output is improper, see Table 5-6.
8. High-frequency ripple in either 15 V supply.	a. Break in black ground lead to TP3. Check and repair as necessary. b. Oscillation in L. V. Supply PC board A2 due to defective transistor or open bypass capacitor. Locate source with oscilloscope and replace as necessary. (See Step 11.)
9. Jitter in -15 V supply (output should be stable with < 0.1 mv jitter.)	a. Check primary reference diode A2CR1 and replace as necessary. b. Check for leaky capacitor A2C7 and replace as necessary. c. Check for noisy resistor A2R17, A2R18, A2R19, or A2R24 and replace as necessary. d. Check for noisy A2Q6, A2Q7, A2Q8.
10. Jitter in +15 V supply (output should be stable with < 0.1 mv jitter.)	a. Check -15 V supply first - see Step 9 above. b. Check for noisy resistor A2R9, A2R10, A2R11, or A2R12 and replace as necessary. c. Check for noisy A2Q2, A2Q3, A2Q4.
11. Oscillation in either 15 V supply.	a. Check bypass capacitors A2C1 through A2C7 and replace as necessary. b. Check output filter capacitors C12A or C12B and replace as necessary.
12. +100 V supply output measures +145 V.	a. Case of Q1 is shorted to main chassis. Check condition and repair or replace as necessary. b. Defective transistor Q1, or socket, on main chassis. Check and replace as necessary. c. Check for short in leads of neon bulb DS3 adjacent to A1.
13. +100 V supply output only about +10 V; both 15 V supplies OK.	a. Defective transistor Q1, or socket, on main chassis. Check and replace as necessary. b. Check for open ground lead to Q1 and repair as necessary.
14. Excess ripple or poor regulation in +100 V supply.	Marginal performance from transistor Q1 on main chassis. Select and install better 2N1537 transistor in Q1 position. Check for proper performance within range of anticipated line voltage variations.
15. +100 V supply output is less than +97 V.	Marginal performance from A2Q10. Select and install 2N3638A transistor with higher β in A2Q10 position.

Table 5-4. Trouble Shooting the Sweep Generator Circuit

Trouble Indication	Suggested Cause and Remedy
1. Sweep Generator inoperative. (No sweep output, either for OUTPUT jack or swept-frequency drive.)	a. Check transistor A3Q7 and replace as necessary. b. Check transistor A3Q4 and diode A3CR4 and replace as necessary. c. Check transistor A3Q5 and replace as necessary.
2. 40 V sweep output is too low.	Excessive gain from A3Q2 circuit. Check A3Q2 and associated components. Replace as necessary.
3. 40 V sweep output is too high.	a. Marginal performance from transistor A3Q2. Select and install 2N3565 transistor with higher β. b. Check resistors A3R7 and A3R8 and diode A3CR2 and replace as necessary.
4. No sweep on fast ranges; OK on slow.	a. Marginal performance from transistor A3Q4. Select and install 2N3565 transistor with higher β. b. Check transistor A3Q2 for shorts. Replace as necessary.
5. Sweep triggers only when SWEEP TRIGGER switch is in FREE RUN position.	a. Marginal performance from transistor A3Q1. Select and install 2N3565 transistor with higher β. b. Short or other defect in A3Q2 circuit. Check A3Q2 and associated components and replace as necessary.
6. Sweep ramp waveform becomes non-linear near top.	Check transistor A3Q5 and replace as necessary.
7. Notch in sweep ramp waveform near top.	a. Check transistor A3Q5, A3Q6, or A3Q7 and replace as necessary.
8. Oscillation in sweep output.	One or more defective transistors on Sweep PC board A3. Locate source with oscilloscope and replace as necessary. Check particularly transistors A3Q4 through A3Q7.
9. 40 V sweep output retraces to -15 V instead of 0 V.	Check diode A3CR7 and replace as necessary.
10. Sweep at SWEEP OUT jack is pulsed at low end instead of having linear ramp appearance.	a. Defective Cathode Supply PC board A1. Check sweep input impedance converter circuit including A1Q11 and A1Q13. Replace as necessary. b. Check transistor A7Q4 in sweep output circuit on PC board A7 and replace as necessary. c. Defective contact on F_2 potentiometer. Check F_2 potentiometer for linear performance and replace as necessary. (May require factory-type recalibration.) d. Defective Markers PC board A4. Check input circuit of A4, including summing resistors A4R30, A4R5, and A4R53.
11. 15 V sweep does not start at 0 V.	a. Defective transistor A7Q4, or socket. Check and replace as necessary. b. Transistor A7Q5 replaced by a PNP unit. Check that A7Q5 is a 2N699. c. Diode A7CR1 defective. Check and replace as required.
12. Improper sweep amplitude supplied to F_2 potentiometer from A7-23.	Check transistor A7Q5 and resistors A7R9 or A7R10, and replace as necessary.
12A. SWEEP light inoperative.	Check transistor A3Q15 and associated components, and replace as necessary.
13. Sweep signal is OK at F_2 potentiometer, but improper at OUTPUT SWEEP jack.	a. Check transistor A7Q4 and replace as necessary. b. Check resistors A7R4 and A7R5 and replace as necessary.
14. Low-voltage starting point of 15 V sweep moves up and down with adjustment of the F_1 potentiometer.	Defective connection of -15 V lead to A7-10. Check and repair as necessary.
15. Retrace pulse at A7-17 shows "double" pulse characteristic consisting of short spike at lead end.	a. Check resistors A3R33 and A3R34 for proper values. Replace as necessary. b. Check transistors A3Q12 and A3Q13 and replace as necessary.
16. Sweep time shorter than selected with SWEEP TIME control.	Check transistor A3Q4 and replace as necessary.

Table 5-4. Trouble Shooting the Sweep Generator Circuit (continued)

Trouble Indication	Suggested Cause and Remedy
17. Sweep time longer than selected with SWEEP TIME control.	a. Marginal performance from transistor A3Q2. Check 40 V sweep. If it exceeds 42 V, select and install 2N3565 transistor with higher β. b. Check A3R7, A3R8, and A3CR2 and replace as necessary. c. Check sweep time resistors R30 and R31 on front panel and replace as necessary.
18. Sweep time incorrect or erratic on 10-sec range, OK on 1-sec range.	a. Defective or marginal transistors A3Q4-A3Q7. Check and replace with higher-β units as necessary. b. Check sweep time capacitor A7C4 and replace as necessary.
19. Sweep time is 0.2 sec on 0.1-sec range, OK on 1-sec range.	Check sweep time capacitor A7C2 and replace as necessary.
20. Improper delay time between sweeps (normal delay interval is 1.7 - 2.7 ms).	a. Unsatisfactory performance from A3Q12, A3Q13, or A3Q14. Transistors with low β shorten the delay interval; transistors with high β lengthen it. Check and replace as necessary. b. Faulty capacitor A3C10. Check and replace as necessary.
21. Ripple on 50 V blanking pulse.	Defective +100 V supply. Measure +100 V output. If improper, see Table 5-3 to localize trouble.
22. 50 V blanking pulse has poor rise-time performance.	Check capacitor A3C1 and replace as necessary.
23. Sweep will not trigger from external pulse with minimum amplitude (5 V) and minimum width (10 μs).	a. Improper value of capacitor A3C4. Select and install capacitor with less capacitance to improve low-level trigger performance. CAUTION If A3C4 is reduced to too low a value, the circuit will become self-triggering on the 10-sec. sweep position. b. Marginal performance from transistors A3Q8, A3Q9 and A3Q10. Select and install transistors with higher β.
24. Sweep is self-triggering on 10-sec position with the SWEEP TRIGGER control in the MANUAL or EXTERNAL position.	a. Improper value of capacitor A3C4. Select and install capacitor with a value of 24 pf or greater. Do not use too high a value (see Step 23 above). b. Excessive gain from transistors A3Q8, A3Q9, and A3Q10. Select and install transistors with lower β.

Table 5-5. Trouble Shooting the Helix Overcurrent Protection Circuit and Collector Current Monitoring Circuit

Trouble Indication	Suggested Cause and Remedy
1. Voltage drop across shunt resistor A7R10 is incorrect.	Defective helix shunt resistors A12R2 or A7R10. Check and replace as necessary. (See Addendum A for correct value of A12R2.)
2. Helix overcurrent trip-out occurs erratically.	a. Check transistors A7Q1, A7Q2, or A7Q3 and replace as necessary. b. Defective or magnetized relay A7K1. Check and replace as necessary.
3. Helix overcurrent relay energizes properly when power is turned on, but subsequently de-energizes.	a. Check transistors A7Q1, A7Q2, or A7Q3 and replace as necessary. b. Check for open resistor A12R2 and replace as necessary. (See Addendum A for correct value of A12R2.)
4. Helix overcurrent relay does not trip when overload occurs.	a. Check transistor A7Q1 for shorted condition and replace as necessary. b. Improper value of resistor A12R2 for the desired trip-out current. (See Addendum A for correct value.
5. Collector current-monitoring voltage drop measured between A12TP1 and TP2 (units with Stewart/WJ tubes only) is outside the specified range.	Defective collector monitoring resistor A12R13. Check and replace as necessary.

Table 5-6. Trouble Shooting the Heater Supply and Heater Overvoltage Protection Circuits

Trouble Indication	Suggested Cause and Remedy
1. Voltage output is very low (1 - 2 V).	a. Defective transistors A6Q6 or A6Q7 or Zener diode A6CR10 in Heater Supply PC board A6, or Q5 on main chassis. Check and replace as necessary. b. Half-open secondary winding between terminals 15-16-16A-17 of low voltage transformer T1. Check voltage developed across each half of the winding. Replace T1 if necessary. c. Check rectifier diode A15CR7 and replace as necessary.
2. Excessive ripple or poor regulation of 6.3 V dc output.	a. Check zener diode A6CR3 and replace as necessary. b. Check transistors A6Q6 and A6Q7 and replace as necessary.
3. Heater overvoltage protection circuit does not trip out when overvoltage occurs.	a. Check transistor A6Q8 and diodes A6CR4 or A6CR5 and replace as necessary. b. Check relay A14K1 and replace as necessary.

Table 5-7. Trouble Shooting the -100 Volt Supply

Trouble Indication	Suggested Cause and Remedy
1. Supply cannot be set to -100 V; output is about -120 V.	Check transistor A6Q1 and replace as necessary.
2. Excessive ripple or poor regulation in supply output.	a. Check transistors A6Q2-A6Q5 and diode A6CR2 and replace as necessary. b. Check rectifier diode A15CR1 on the main chassis and replace as necessary.

Table 5-8. Trouble Shooting the Anode Supply

Trouble Indication	Suggested Cause and Remedy
1. Supply loses regulation when operated with plug-in unit which has control feedback set for an output voltage near either supply limit (+30 V or +300 V).	a. Check tube A10V4 by substitution, and replace if necessary. b. Check rectifier diode A15CR2 on the main chassis and replace as necessary.
2. Supply Oscillates.	a. Check resistor A10R76 and capacitor A10C20 on A10V4 socket and replace as necessary. b. Excessive gain in circuit of A6Q10 and A6Q11. Check circuit components. If necessary select and install 2N3565 transistors with lower β.
3. Supply loses regulation with small drop in line voltage (e. g. to 103 V).	Poor regulation performance of -100 V supply. See Table 5-7.

Table 5-9. Trouble Shooting the Cathode Supply

Trouble Indication	Suggested Cause and Remedy
1. Poor regulation in supply output with variations in line voltage.	a. Defective regulator tubes V1, V2, or V3. Check by substitution and replace all three tubes as a group if replacement is necessary. b. Check +100 V supply regulator transistor Q1 on the main chassis, and replace as necessary. c. Marginal performance from transistors A1Q2, A1Q3, A1Q4 and A1Q5. Select and install 2N3646 transistors with higher β. CAUTION Excessive β will produce ringing in response to pulsed load on cathode supply.
2. Erratic output voltage from cathode supply.	a. Check dual transistor A1Q1 and replace as necessary. (May require factory-type recalibration.) b. Check for open transistor A1Q2 and replace as necessary. c. Sweep retrace discharge tube A10V5 arcing. Check by substitution and replace as necessary.
3. Supply output ripple is the same when the FREQUENCY switch is in the SINGLE position as when it is in a SWEEP position (should reduce by about 4:1 in the SINGLE position).	a. Check transistors A1Q8 and A1Q9 and replace as necessary. b. Check capacitor A1C11 and replace as necessary.

Table 5-9. Trouble Shooting the Cathode Supply (continued)

Trouble Indication	Suggested Cause and Remedy
4. Supply output voltage does not follow the curve presecribed.	Defective diode shaper board A13.
5. The supply output voltage set with the F_2 potentiometer in single-frequency mode is different from the voltage set with any other control turned to the same dial frequency (MANUAL SWEEP control must be fully CW).	a. Check transistors A1Q10, A1Q11, A1Q12, or A1Q13 and replace as necessary. b. Check capacitors A1C1 or A1C2 and replace as necessary. c. Check summing resistor circuits in the Markers PC board A4. d. Resistors A1R3 or A1R4 out of tolerance. Check and replace as necessary.* e. Defective frequency control potentiometer, malfunctioning dial mechanism, or improperly adjusted calibration resistors. Return the instrument to the factory for recalibration.

*May require factory-type recalibration.

Table 5-10. Trouble Shooting the Modulator and Transfer Oscillator

Trouble Indication	Suggested Cause and Remedy
1. No grid voltage output at A12-TP3 when the FREQUENCY Mode Selector is turned OFF (Should be -25 V or -75 V)	a. Improper output voltage from -100 V supply. Check output voltage between TP10and TP11 using an oscilloscope with floating connections. If output is incorrect, see Table 5-7. WARNING This is a high voltage measurement. Use a floating, insulated meter and set the output frequency to the low end of the band to reduce the reference level of the "O" line." b. Defective Modulator PC board A5. Check output waveform at C18 (Figure 5-1). Level should be 0 V for rf full on; about +11 V for rf off. If modulator output is OK, the fault is in the Transfer Oscillator PC board A9 or in the elevated supply. If modulator output is incorrect, check that the proper blanking input of about +2 V is being supplied to A5-W by the Sweep PC board A3. Clear any fault in A3 by referring to Table 5-4. Then check the circuits of A5Q8, A5Q3, and A5Q5 in the modulator. Replace components as necessary. c. Defective Transfer Oscillator PC board A9 (if waveform check at C18 shows the proper signal is being supplied from the modulator). Check output waveform between A9TP12 and TP11 using an oscilloscope with floating connections. A9TP12 should be +5 V with respect to TP11 for rf off and 0 V for rf on. If this output is correct, the fault is in the elevated supply, in the circuit of A12Q1. If transfer oscillator output is incorrect, check components in A9. WARNING Check components with high voltage off. d. Defective A9 demodulator driver stages. Check A9CR3, A9CR4, A9Q4 and A9CR5 and associated components. e. Defective rf oscillator stage. Check for oscillator output at the junction of A9C4 and A9C6. If components are replaced, adjust the oscillator frequency to obtain optimum demodulated power following the procedure of Step 3 b. below. f. Defective oscillator amplifier/modulator. Check A9Q2, A9Q3, A9CR2, A9CR1 and associated components, particularly coupling capacitors.
2. GRID voltage output at A12-TP23 remains at -25 V or -75 V when the FREQUENCY Mode Selector is turned to SINGLE.	a. Localize the trouble to the Modulator or Transfer Oscillator or Elevated Supply PC boards by making the measurements of b. and c. in Step 1 above. b. Defective component in modulator output stages. Check A5Q3 or A5Q5 and associated components. c. Defective component in transfer oscillator. See Steps d., e., and f. of Step 1 above.
3. Low GRID output voltage at A12TP23.	a. Improper output voltage from -100 V supply. See Step 1 a. above. b. Diode A9CR5 shorted. Check and replace as necessary. c. Transfer oscillator output improperly adjusted. Check transfer oscillator output waveform as directed in Step 1 c. above, using fast-rise oscilloscope and operating the Model 6400 in square wave mode. Note the position of the adjustment screw of TRANSFER OSC FREQ ADJ A9C5. Then carefully make a slight trial adjustment in each direction to see if the rise time of the transfer oscillator output waveform can be improved. A9C5 should be set to the

Table 5-10. Trouble Shooting the Modulator and Transfer Oscillator (continued)

Trouble Indication	Suggested Cause and Remedy
3. (continued)	position that gives the fastest rise time in the transfer oscillator output waveform. The rise time should be about 0.1 μs. If output waveform has an amplitude of less than 5 V, check the transfer oscillator components as in Steps 1-d. through f. above, and replace as necessary. d. Defective modulator circuit in elevated supply. Check A12Q1 and associated components.
4. Excess ripple in GRID output voltage at A12TP23.	a. Poor regulation in low or high-voltage supplies. Check supplies for ripple and refer to the appropriate table to localize trouble. b. Marginal performance from transistor A9Q1. Check A9Q1 by substitution. (Excess ripple may be produced with satisfactory output level.) If A9Q1 is replaced, adjust A9C5 for best rise time as directed in Step 3 c. above. c. Oscillation or ripple pickup from modulator or leveler. Check signal inputs to transfer oscillator at A9-3 and A9-4 (C18 and C19) for excess ripple. If found, localize the source by circuit tracing with an oscilloscope.
5. Retrace blanking cannot be obtained; rf output is properly turned off when FREQUENCY switch is OFF. (Otherwise, see Step 1 above.)	a. Improper blanking signal supplied by Sweep PC board A3. Check blanking signal supplied to A5-W, using an oscilloscope, while operating the Model 6400 in a sweep mode. The signal should be a rectangular pulse with an amplitude of about +12 V during the sweep and +2 V during retrace. If an improper signal is being supplied, refer to Table 5-4 to localize trouble. b. Defective switch(s) or wiring between A5-X and ground. Check circuits of S12, S13, and S14. (See Figures 4-16, 4-17, and 4-18.)
6. Internal square-wave modulation is inoperative; EXT AM and blanking OK.	a. Defective component is 2 Kc oscillator circuit. Check waveform at junction of A5R4 and A5C2 using an oscilloscope. If no output is generated, check A5Q1, A5C1, and R36, and replace as necessary. b. Defective gate or multivibrator input stage. Check A5Q2 and A5Q4 and associated components. Replace as necessary.

Table 5-11. Trouble Shooting the Marker Generator

Trouble Indication	Suggested Cause and Remedy
1. No Markers	a. Defective transistors A4Q2, A4Q3, A4Q8, A4Q9, A4Q14, A4Q15, or A4Q19, caused by connecting A4 board with power on. Check and replace as necessary. b. Defective resistor in amplitude selection circuit. Check A4R73, A4R74, A4R75, A4R77 and replace as necessary.
2. Markers do not have identical amplitude.	Marginal performance from A4Q6, A4Q12, or A4Q18. Check the transistor in the circuit producing the lowest amplitude marker and replace it with a 2N3638A transistor having higher β if necessary.
3. One or more markers do not appear at the selected frequency.	Defective input transistor A4Q1, A4Q7, or A4Q13 in the malfunctioning circuit. Check and replace as necessary.*
4. Oscillation in markers circuit.	Improper value of A4C2, A4C4, or A4C6. Locate the circuit producing the oscillations by using an oscilloscope. Check the capacitor in that circuit and adjust its value by replacement or padding as necessary to eliminate oscillations.

*May require factory-type recalibration.

5.5 CALIBRATION

(Refer to Paragraph 5.3.5 for rf output frequency calibration.)

5.6 REPLACEMENT OF FREQUENCY AND MARKER POTENTIOMETERS.

CAUTION

If any of the frequency or marker potentiometers are replaced in the field, the instrument must be recalibrated at the factory or in accordance with Paragraph 5.5 above. The unit can be operated without calibration, but frequency specifications will not be met.

NOTE: The F_1 and F_2 potentiometers can be removed without dropping the front panel. Removal of the M_1, M_2 or F_0 potentiometers requires dropping the front panel forward for access. (See Paragraph 5.6.1 for the procedure.)

5.6.1 REMOVAL OF FRONT PANEL. To remove the front panel and tilt it forward from the chassis for access to the dial mechanism, proceed as follows:

a. Remove the top cover by removing its nine attaching screws.

b. Remove the right and left handle sides by removing the four corner screws.

c. Remove the five FREQUENCY and MARKERS control knobs.

d. Remove the panel dial mechanism cover by removing the Phillips screw from each end.

(procedure continues on pg. 5-31)

TABLE 5-12. MAXIMUM ANODE CURRENT FOR VARIAN TUBES.

TYPE	FREQUENCY RANGE	ANODE TRIP CURRENT
VA-183AA	.99 to 2.1 GHz	11 ma
VA-183A	1 to 2 GHz	"
VA-186AA	1.4 to 2.5 GHz (Tentative)	"
VA-184AA	1.7 to 4.2 GHz	"
VA-184A, VA184A Spec.	2 to 4 GHz	"
VA-187AA	2.5 to 5.5 GHz (Tentative)	"
VA-187A	2.6 to 5.2 GHz (Tentative)	"
VA-185AA	3.5 to 6.75	"
VA-185AC	3.6 to to 4.3, 5.9 to 6.5 GHz	"
VA-185AB	3.7 to 8.3 GHz	"
VA-185A	4 to 8 GHz	"
VA-160A, VA-160W	4 to 8 GHz	"
VA-160A, Special Spec. #2	5.3 to 6.5 GHz, Spec. #2, 5.9 to 6.5	"
VA-160C	5.4 to 5.9 GHz	13 ma
VA-173A, VA-173A Spec. #1	7 to 12.4 GHz	11 ma
VA-173E, VA-173W	8 to 12.4 GHz	"
VA-175A	8 to 12.4 GHz	"
VA-177A	10 to 15.5 GHz	7 ma
VA-162A Spec. #3	10 to 18 GHz	"
VA-162A Special	10 to 20 GHz	"
VA-162A Spec. #2	10 to 20 GHz Hi Power	"
VA-162A, VA-162W	12.4 to 18 GHz	"
VA-163A, VA-163A Spec. #1	18 to 26.5 GHz, VA-163A Spec. #1 17 to 26.5 GHz	"
VA-163A Spec. #2	20 to 28 GHz	"
VA-164A, 164A Spec. #1	26.5 to 40 GHz	"

e. Remove the plate which retains the coiled cable and TB901 from the right side of the chassis by removing two Phillips screws which attach the plate.

f. Release the front panel from the chassis by removing the three Phillips screws from each side and the two Phillips screws from the bottom.

g. Carefully tilt the top of the front panel outward while keeping the bottom edge close to the chassis as required by the wiring harnesses. Rest the plate removed in Step e. above at a convenient point to avoid damage to the TB901 wiring.

5.6.2 REPLACEMENT OF F_1 POTENTIOMETER.

Proceed as follows:

a. Remove top cover.

b. Unsolder leads from potentiometer terminals.

c. Rotate F_1 control knob full counterclockwise (CCW) to its lower mechanical stop. It is important to remember the exact position of the indicator when the stop is reached, as this position must be maintained when the new potentiometer is installed.

d. Loosen both potentiometer shaft gear hub set screws.

CAUTION

Do not disrupt relative position of the F_2 potentiometer shaft gears. Make a pencil mark on the mounting plate and gear and realign before meshing the F_1 gear. If the F_2 gears are moved and not realigned, the mechanical stops will not be oriented and realignment must be performed according to the procedures of Paragraph 5.6.3, starting with Step h.

e. Slide gear forward.

f. Remove potentiometer retaining nut and washer. While holding nut, washer and gear, withdraw potentiometer from mounting plate, noting orientation of potentiometer terminals.

g. Insert new potentiometer engaging washer, nut and gear. Tighten retaining nut, remembering orientation of potentiometer terminals.

h. Position the F_1 potentiometer shaft full clockwise (CW) as viewed from the shaft end. This can best be accomplished by lightly tightening one gear set screw and while the gear is disengaged, finger turning the shaft full clockwise. Loosen the set screw.

i. Before engaging the gear, check to see if the dial indicator is in the exact position as it was before and check to see if the F_2 gear lines up with its pencil mark.

j. Engage the F_1 potentiometer shaft gear and tighten both screws.

NOTE: If the indicator is not in the exact position as noted in Step c., do not position it by turning the F_1 dial cord drum. Instead, disengage the gear and reposition the indicator.

5.6.3 REPLACEMENT OF F_2 POTENTIOMETER.

a. Remove the top cover, the five control knobs, and the dial mechanism cover.

b. Unsolder the three leads from the potentiometer terminals. Remove the three small screws which hold the coiled wire bracket to the back of the potentiometer. The coiled wire is now free.

c. Rotate F_1 knob full counterclockwise (CCW) and the F_2 knob full clockwise (CW).

d. Loosen F_2 potentiometer gear hub set screws on both gear hubs.

e. Remove F_2 potentiometer by turning the potentiometer case in a clockwise direction as viewed from the shaft end.

f. Insert new potentiometer and tighten by turning in a counterclockwise direction.

g. Tighten set screws on gear hub closest to the mounting plate.

h. Disengage the idler gear connecting the F_1 potentiometer shaft gear to the F_2 potentiometer body gear.

i. Set the upper mechanical stop. This stop can be seen as a bent tooth on the gear on the F_2 potentiometer shaft and a small extension on the F_2 dial indicator shaft gear. The stop must be set below the center line of the F_2 dial indicator gear and the F_2 potentiometer gear as the F_2 knob turns clockwise.

It may take a few attempts but no difficulty should be encountered.

j. Tighten the potentiometer shaft gear set screws.

k. Rotate the F_2 knob counterclockwise until the F_2 indicator is approximately 1/64" from the F_1 indicator. Now, while holding the F_2 knob so as to maintain the 1/64" distance, rotate the entire F_2 potentiometer counterclockwise (CCW) until the mechanical stop is felt. If the indicators touch because the F_2 knob was allowed to turn after the stop was reached, a slight clockwise turn on the F_2 knob will separate them.

l. Very carefully engage the idler gear between the F_1 potentiometer shaft gear and the F_2 potentiometer body gear (the one closest to the mounting plate) and tighten set screws.

The lower and upper mechanical stops are now set. A gap should be maintained between indicators over the entire distance of the dial. Adjustments should be made beginning with Step h. if gap is not maintained.

m. After the stops have been set, run the F_2 indicator full clockwise (CW) and the F_1 indicator to approximately 50 on the logging scale.

n. Remove the three screws from the back of the F_2 potentiometer.

CAUTION

Do not let the back of the potentiometer come off.

o. Secure the coiled wire bracket to the back of the potentiometer, and solder the three leads to the potentiometer terminals.

5.6.4 REPLACEMENT OF M_2 POTENTIOMETER.

a. Unsolder the wires to potentiometer terminals.

b. Turn the M_1 and M_2 knobs full counterclockwise (CCW).

c. Remove retaining ring and thrust washer from the M_2 knob shaft.

d. Loosen the two set screws on the M_2 knob shaft gear hub.

e. Loosen the M_2 dial cord hub and press M_2 knob shaft about halfway out.

f. Loosen potentiometer shaft gear hub set screws.

g. Remove potentiometer retaining nut and washer and remove M_2 potentiometer remembering orientation of potentiometer terminals.

h. Position idler gear (with planetary gear) and new potentiometer shaft full clockwise (CW) as viewed from the front panel.

i. Insert new potentiometer and tighten retaining nut remembering potentiometer orientation.

j. Engage potentiometer shaft gear and tighten set screws. Make sure the potentiometer shaft is full clockwise (CW).

k. Press M_2 knob shaft into place and replace thrust washer and retaining ring.

l. Engage M_2 knob shaft gear with idler gear and potentiometer shaft gear.

m. Tighten set screws on M_2 knob shaft gear.

n. Rotate M_2 knob fully counterclockwise (CCW).

o. Rotate M_2 dial cord CCW until dial indicators are approximately 1/64" apart.

p. Tighten M_2 dial cord drum set screw.

5.6.5 REPLACEMENT OF THE M_1 POTENTIOMETER.

a. Remove the Helix Overcurrent PC board A7, and the "In Voltage Calibrate" PC board assembly 950853. This will permit a wrench to be inserted from the left side of the gear assembly as viewed from the front of the unit.

b. Position M_1 and M_2 control knobs full CCW. Note position of indicators.

c. Loosen the M_1 potentiometer shaft gear hub set screws.

d. Remove M_1 potentiometer retaining nut and withdraw M_1 potentiometer, remembering orientation of potentiometer terminals.

e. Insert new potentiometer. Tighten retaining nut.

f. Replace M_1 potentiometer shaft gear making sure that the M_1 indicator is in previous position and the M_1 potentiometer shaft is full clockwise (CW).

g. Tighten set screws on potentiometer shaft gear.

h. Replace Helix Overcurrent PC board and assembly 950853.

i. Resolder leads.

5.6.6 REPLACEMENT OF THE F_0 POTENTIOMETER.

a. Rotate the F_1, F_0, and F_2 control knobs full counterclockwise (CCW).

b. Unsolder the leads to the F_0 potentiometer terminals.

c. Remove the F_1 knob shaft retaining ring and thrust washer.

d. Loosen the F_1 dial cord drum set screws, remembering the exact position of F_1 indicator.

e. Move F_1 knob shaft forward disengaging F_1 knob shaft gear. Loosen F_1 knob shaft gear hub set screws.

f. Slide F_1 knob shaft forward until inner locking ring bottoms on F_1 knob shaft gear.

g. Loosen set screws on F_0 potentiometer shaft gear.

h. Loosen potentiometer retaining nut.

i. Withdraw potentiometer remembering orientation of potentiometer terminals.

j. Insert new potentiometer positioning shaft full clockwise (CW) as viewed from the shaft end.

k. Tighten potentiometer retaining nut.

l. Engage F_0 potentiometer shaft gear and tighten two set screws.

m. Loosen set screw on F_0 dial cord drum and note position of indicator. Rotate F_0 knob full counterclockwise (CCW). The stop of the potentiometer should be felt.

n. Position the F_0 indicator to position as noted in step m.

o. Tighten F_0 dial cord drum set screw.

p. Replace F_1 knob shaft into position and replace thrust washer and retaining ring.

q. With the F_1 potentiometer shaft fully clockwise (CW), slide the F_1 knob shaft gear up and intermesh with F_1 potentiometer shaft gear. Tighten gear set screws.

r. Rotate F_1 knob shaft fully counterclockwise (CCW) and tighten F_1 dial cord drum after positioning indicator as it was before, step d. above.

s. Resolder leads.

5.7 REPLACING THE MICROWAVE TUBE. (See Figure 5-3).

5.7.1 GENERAL. The microwave tube is located in the lower left compartment of the chassis, as shown in Figure 5-3. The elapsed time indicating meter location is visible. Because tubes from different manufacturers are used in the Model 6400 Series, different installation procedures are required, as given in Paragraphs 5.7.2 and 5.7.3. After replacing a tube, follow the procedure of Paragraph 5.7.4 to reset supply voltages as required by the new tube before turning power on. Refer to Paragraph 5.4.6 for information on tube ageing and warranty replacement procedures.

CAUTION

Use non-ferrous tools when removing and installing microwave tube.

NOTE: Always retain the data sheet supplied with the new tube for future reference, by placing it in the envelope at the rear of this manual.

5.7.2 UNITS WITH WATKINS-JOHNSON (STEWART) TYPE BWO TUBES.

a. Remove the bottom cover plate.

b. Remove the four (4) mounting screws which hold the tube to the mounting plate. This plate can be seen from the bottom of the unit.

c. Unsolder the tube leads at the Elevated Supply PC board (A12). The diagram below locates the terminals used on the elevated supply PC board.

d. Disconnect the two supply connection plugs which provide power to the BWO, P40 and P41, which are shown in Figure 5-3. Replacement tubes supplied by Alfred Electronics are provided with proper plugs installed for quick connection. In the event that there is any question on color-coding of tube lead connections through the plugs to the elevated supply, the connection color-code is tabulated below:

P40/J40 Pin	Elevated Supply A12 Terminal	BWO Connection	Stewart BWO Tube Lead
A	5	Anode	Blue
C	9	Heater +	Brown
B	7	Heater -	Black
D	20	Helix	Red
E	17	Collector	Orange
F	15	Grid	Green
Single-pin P41/J41	11	Cathode	Yellow
Ground Lead	-	ground	Not used

e. Disconnect the instrument rf line from the tube rf output connection. On units with baluns, also remove the balun from its mounting plate by removing the attaching screws. Do not detach the balun from its connecting wires to the tube housing. The balun furnished with the replacement tube must be installed with that tube, and the old balun remains a part of the tube removed.

f. Install the replacement tube by the reverse of the above procedure.

g. Check tube voltages in accordance with Paragraph 5.7.4.

h. Replace the elapsed time meter M1.

5.7.3 UNITS WITH VARIAN BWO TUBES.

a. Remove the bottom cover plate.

b. Remove the six (6) mounting screws which hold the tube to the side of the unit.

c. Unsolder the tube leads at the Elevated Supply PC board (A12). The diagram below locates the terminals used on the elevated supply PC board.

d. Disconnect the two supply connection plugs which provide power to the BWO, P40 and P41, which are shown in Figure 5-3. Replacement tubes supplied by Alfred Electronics are provided with proper plugs installed for quick connection. Disconnect the blue lead from the chassis screw adgacent to the tube. In the event that there is any question on color-coding of tube lead connections through the plugs to the elevated supply, the connection color-code is tabulated below:

P40/J40 Pin	Elevated Supply A12 Terminal	BWO Connection	Varian BWO Tube Lead
A	5	Anode	Red
C	9	Heater +	Yellow
B	7	Heater -	Yellow
D	20	Helix	Brown
E	17	Collector	Not used
F	15	Grid	Orange
Single-pin P41/J41	11	Cathode	Green
Ground Lead (solder-lug connected to chassis)	-	ground	Blue

CAUTION: The BLUE lead from the Varian BWO tube must be connected to a chassis screw for proper grounding. If this lead is broken or disconnected, tube damage may occur. The ground connection of the tube exterior through the mounting hardware and/or the shell of the rf output connection line does not provide the internal ground reference required for proper operation. The proper internal ground is provided ONLY when the BLUE lead is properly connected to chassis ground. The tube must never be operated without this ground connection.

e. Disconnect the instrument rf line from the tube rf output connection.

f. Install the replacement tube by the reverse of the above procedure.

g. Check tube voltages in accordance with Paragraph 5.7.4

h. Replace the elapsed time meter M1.

5.7.4 ADJUSTMENT OF POWER SUPPLY VOLTAGES FOR THE REPLACEMENT TUBE.

a. Before turning power on, determine whether the anode supply feedback resistor A12R14 in the elevated supply must be changed. To do this, compare the anode voltage requirement listed on the specification sheet shipped with the tube with the tabulation of supply output voltages versus feedback resistor values given in Figure 5-4. If the indicated feedback resistor value does not agree with the resistor installed in the plug-in unit on Elevated Supply PC board A12, install a replacement resistor of the correct value.

b. Turn power on and check all supply and tube voltages in accordance with Paragraph 5.2 and Table 5.1.

c. ANODE ADJ. control A12R9 with a non-metallic screwdriver. This control has a limited range, and if it is necessary to increase anode voltage above the specified value to obtain rated power output, the value of A12R14 may have to be increased. (See item 1 of paragraph 5.3.2. to check output power.)

d. NOTE: Always retain the test data sheet for the new tube for future reference, by placing it in the envelope at the rear of the manual. Discard the data sheet for the old tube to avoid confusion.

5.8 REPLACEMENT OF OTHER COMPONENTS AND CONTROLS.

5.8.1 REPLACEMENT OF FRONT PANEL SWITCHES. To replace multi-section switches, refer to the wiring diagrams given in Figures 4-17 and 4-18. For all other switches and potentiometer controls, refer to the overall schematic diagram 900775 in Section 7. As you disconnect each wire from the defective switch or control, note its wire color on the diagram to simplify resoldering each wire to the proper terminal on the new switch. If there is any question as to the correctness of the new installation, check by circuit-tracing in accordance with the schematic or wiring diagrams before power is applied.

5.8.2 REPLACEMENT OF PARTS ON PRINTED CIRCUIT BOARDS. Parts on all PC boards are identified by silkscreened reference designators. They are shown on both the simplified schematics (Figure 4-2 through 4-16) and the overall schematics in Section 7. To remove individual components from PC boards, first make a diagram showing the exact orientation and connection of the part to simplify future installation. Use a low-power soldering iron (50 watts maximum) and apply heat sparingly to the lead of the part to be replaced. (The simplest way to remove a transistor is to cut its leads, and then unsolder the ends of the leads that are left in the board.) When removing the device leads, use a toothpick or a small awl to clear the holes of softened solder. Avoid excessive heat, and always ground the soldering iron to prevent leakage voltage from damaging the component.

When connecting the replacement component, trim the leads so they will penetrate the board abour 1/16 inch with the component positioned about 3/16 inch above the board. Hold the part on the component side, and solder the leads from the other side. If possible, hold the component lead on the component side with a tool which will act as a heat sink, such as a pair of needle-nose pliers. Solder with the absolute minimum of heat necessary to completely melt the solder, to avoid overheating. Use a high-quality rosin core solder only; never use paste flux. After soldering, trim off excess leads and flux.

If a break occurs in the etched copper circuit, repair it by soldering a short length of tinned copper wire across the break. Copper that lifts off the board should be cemented in place with a quick-drying acetate base cement having good electrical insulating properties.

5.8.3 REPLACEMENT OF CHASSIS-MOUNTED PARTS. Most parts mounted directly on the chassis or on terminal boards are identified by silkscreened reference designators. Parts not so identified are called out in Figures 5-1 and 5-3 for easy reference. These parts are all shown on the overall schematic diagram, 900845, in Section 7, and most of them also appear on the applicable simplified schematic diagrams in Section 4. For soldering work, a 50-watt iron and high-quality rosin core solder should be used. Avoid overheating, and use a pair of needle-nose pliers as a heat sink on the component end of the lead as an extra precaution.

5.8.4 ADJUSTMENTS REQUIRED AFTER PARTS REPLACEMENT. Refer to Paragraph 5.3 for adjustments required after replacement of parts.

SECTION 6 - PARTS LIST

LIST OF FSC CODES FOR TRUE MFRS.

FSC Number	Full Name and Address of Vendor
00656	Aerovox Corporation, 740 Belleville Ave., New Bedford, Mass.
00686	Film Capacitors, Inc., 100 East 8th Street, Pabsaic, N.J.
00816	Hughes Aircraft Co., Vacuum Div., 500 Superior Ave., Newport Beach, Calif.
00853	Sangamo Electric Co., P.O. Box 128, Pickens, S.C.
00866	Goe Engineering Co., 219-21 S. Mednik Ave., Los Angeles, Calif.
01121	Allen Bradley Co., 136 W. Greenfield Ave., Milwaukee, Wisc.
01281	Pacific Semiconductor Co., 10451 W. Jefferson Blvd., Culver City, Calif.
01456	Microwave Development Laboratories, 87 Crescent Road, Needham Heights, Mass.
01963	Cherry Electrical Products Corp., Box 439, Highland Park, Ill.
02111	Spectrol Electric Corporation, 17070 E. Gale Ave., City of Industry, Calif. 91745
03508	G.E. Semiconductor, Electronics Park, Syracuse, N.Y., 13201
03565	Dayton Electronic Products Co., 117 E. Helena St., Dayton, Ohio
03782	Alfred Electronics, 3176 Porter Drive, Palo Alto, California 94304
04009	Arrow-Hart, & Hegeman Elec. Co., 113 Hawthorne St., Hartford, Conn.
04713	Motorola Semiconductor Products, Inc., P.O. Box 955, Phoenix, Arizona
05783	Stewart Engineering Co., 467 Bean Creek Rd., Santa Cruz, Calif.
05820	Wakefield Engineering Inc., 139-T Foundry St., Wakefield, Mass.
06049	Topaz, 3802 Houston, San Diego, California 92110
06555	Beede Electrical Instrument Co., Inc., Penacock, N.H.
06980	Varian, 611 Hansen Way, Palo Alto, Calif. (BWO)
07029	Radio Corp. of America, Electronic Components & Devices, 415 S. 5th St. Harrison, N.J.
07137	Transistor Electronics Corp., Box 6191, Minneapolis, Minn.
07263	Fairchild Semiconductor, 545 Whisman Rd., Box 880, Mountain View, Calif.
08806	General Electric Corp., Min. Lamp Dept., Nela Park, Cleveland, Ohio
09022	Cornell-Dubilier, 50 Paris St., Newark, N.J. (Mica Caps)
09023	Cornell-Dubilier, 50 Paris St., Newark, N.J. (Electrolytic Caps)
09297	CP Electronics Inc., Columbus, Ind.
11312	Microwave Electronics Div. of Teledyne, 3165 Porter Drive, Palo Alto, Calif.
12060	Diodes, Inc., 9261 Independence Ave., Chatsworth, Calif.
12122	Astrodyne, Inc., 2nd Ave., NW. Ind. Park, Burlington, Mass. 01803
12360	Albany Products, 351 Connecticut Ave., South Norwalk, Conn.
12697	Clarostat Mfg. Co., Washington St., Dover, N.H.
13664	Workman Elec. Prod. Inc., Packing House Rd., Sarasota, Florida 33578
13862	Alasco Rubber & Plastic Corp., 839 Malcom Rd., Burlingame, Calif.
14026	Spatron, Inc., 715 S. Raymond Ave., Alhambra, California 91803
14433	International Telephone & Telegraph, 3301 Electronic Way, W. Palm Beach, Florida
14482	Watkins-Johnson Co., 3333 Hillview, Palo Alto, California
15582	Bay City Screw & Bolt Co., 601 Industrial Way, San Carlos, Calif.
15818	Amelco, 1300 Terra Bella, Mt. View, Calif. 94042
16299	Corning Glass Works, Electronic Products Div., 3906 Electronics Dr., Raleigh, N.C.
16741	Triad Dist. Div. (Litton Ind.) 305 N. Briant St., Huntington, Ind.
17474	Tranex, Inc., 1599 Stierlin Rd., Mountain View, California
17545	Atlantic Semiconductors, Inc., 905 Mattison Ave., Asburg Park, N.J. 07712
17920	Warnecke Electron Tubes, 175 W. Oakton St., Des Plaines, Ill.
18489	Reliable Capacitors Co., 14716 Arminta St., Van Nuys, Calif.
18915	Birtcher Corp., The Industrial Div., 745 S. Monterey Pass Rd., Monterey Park, Calif.
19701	Electra Mfg. Co., 800 North 21, Independence, Kansas
20286	Daytron, Inc., 1269 Terra Bella, Mountain View, California
20649	Universal Metal Products, 5924 N. Western Ave., Chicago 45, Ill.
21030	Beckman Instrument, Inc., Helipot Div., 2500 Harbor Blvd., Fullerton, California
21743	Canseat Corp., 4164 Greenbush Ave., Sherman Oaks, Calif.
22229	Union Carbide, KEMET Elect. Div., Mountain View, California
23880	Standford Applied Engineering, 340 Martan Ave., Santa Clara, Calif.
24220	Gowanda, 179 Broadway Rd., Gowanda, N.Y.
24796	Paralco, Inc., 26181 Avenida Aevoprierto, San Juan Capistrano, California
27014	National Semi-Conductor Corp., 2950 San Ysidro Way, Santa Clara, Calif.
28480	Hewlett-Packard, Paeco Div., 3215 Porter Drive, Palo Alto, California
31918	International Electronics Exchange, 6529 Cambridge St., Minneapolis, Minn. 55426
33173	General Electric Corporation., Tube Dept., 316 E. Ninth St., Owenboro, Ky.
35434	Lectrohm, Inc., 5560 Northwest Hwy., Chicago, Ill.
37942	Mallory Capacitor Co., Div. P.R. Mallory & Co., Inc., 3029 E. Washington St., Indianapolis, Ind.
42190	The Muter Co., 1255 S. Michigan Ave., Chicago 5, Ill.
42498	National Radio Co., Melrose, Mass.
44655	Ohmite Mfg., Co., 3635 W. Howard St., Skokie, Ill.
46384	Penn Engineering, West State St., Doylestown, Penn.
56289	Sprague Electric Co., 91 Marshall St., N. Adams, Mass.
59730	C/O Thomas & Betts Co., 645 Phelps St., San Francisco, California

FSC Number	Full Name and Address of Vendor
70309	Allied Control Co., Inc., 2 East End Ave., New York, New York
70563	Amperite Co., Inc., 600 Palisade Ave., New Jersey
70903	Belden Mfg. Co., Box 5070-A, Chicago, Ill. 60644
71436	Chicago Condenser Corporation, 3253 Armitage Ave., Chicago, Ill. 60647
71450	CTS Corp., 1172 W. Beardsley, Elkhart, Ind.
71590	Centralab, Electronics Div., Globe Union, 934 Keefe Ave., Milwaukee, Wisconsin
71785	Cinch Mfg. Co., 1026 S. Homan Ave., Chicago 24, Ill.
71895	Delavan Mfg. Co., Electro-Sonics Div., West Des Moines, Iowa
71982	Erie Technological Products, Inc., 644 W. 12th St., Erie, Penn.
72012	M. Ducommun Mfg. Co., 580 Fifth Ave., New York , New York 90036
72136	Electro Motive Mfg. Co., Inc., S. Park & John Streets, Williamantic, Conn.
72765	Drake Mfg. Co., 4626 N. Olcott Avenue, Harwood Heights, N.Y. 60656
72983	Stancor Electronics (Essex Wire Corp.) 3501 W. Addison St., Chicago, Ill.
73293	Hughes Aircraft Co., Elec. Comp., Div., 500 Superior Ave., Newport Beach, Calif.
73445	Amperex Electronic Corporation, Box 418, 230 Duffy Ave., Hicksville, N.Y.
73899	JFD Elect. Co., Comp. Div., 15th Ave., at 62nd St., Brooklyn, N.Y.
74542	Hoyt Electrical Inst. Works, Inc., 42 Carleston St., Cambridge, Mass.
74868	Amphenol Corp., Connector Div., 1830 S. 54th Ave., Chicago, Ill.
74970	The E.F. Johnson Co., 1923 10th Ave., S.W. Waseca, Minn.
75376	Kurz Kasch, 1417 S. Broadway, Dayton, Ohio
75382	Kulka Electric Corp., 520 S. Fulton Ave., Mt. Vernon, N.Y.
75042	IRC, Inc., 401 N. Broad St., Philadelphia, Penn.
75497	Lamson & Sessions, 5002 Tiedeman Rd., Cleveland, Ohio
75915	Littlefuse, Inc., 800 E. Northwest Hwy., Des Plaines, Ill.
76433	General Instrument Corp., 65 Gouverneur, Newark, N.J.
76487	James Millen Mfg. Co., Inc., 150 Exchange St., Malden, Mass.
76854	Oak Mfg. Co., Crystal Lake, Ill.
77342	Potter & Brumfield, Div., American Machine & Foundry Co., 1200 E. Broadway, Princeton, Ind.
77557	Reliable Spring & Wire Forms Co., 3167 Fulton Rd., Cleveland, Ohio
78553	Tinnerman Co., Dept. 16-T, P.O. Box 6688, Cleveland, Ohio
78947	Ucinite Corporation, 459 Watertown St., Newtonville, Mass. 02160
79493	J.W. Miller Co., 5915 S. Main St., Los Angeles, Calif. 90003
80294	Bourns, Inc., 1200 Columbia Ave., Riverside, California 92507
81073	Grayhill, Inc., 569 Hillgrove Ave., La Grange, Ill.
81312	Winchester Electronics, Inc., Div. Litton Industries, 19 Willard Rd., Norwalk, Conn.
82389	Switchcraft, Inc., 5555 N. Elston Ave., Chicago 30, Ill.
83186	Victory Engineering, 128 Springfield Ave., Springfield, New Jersey
83701	Electronic Devices, Inc., 21 Grey Oaks Ave., Yonkers, N.Y.
88245	USECO, Div. of Litton Industries, 13536 Saticoy St., Van Nuys, Calif.
89536	John Fluke Mfg. Co., Inc., P.O. Box 7428, Seattle, Wash.
91278	Stoesser Tool & Die, 3366 Fayette Dr., Mountain View, California
91418	Radio Materials Co., 4242 W. Bryn Mawr Ave., Chicago 46, Ill.
91637	Dale Electronics, Inc., (Subs. Lionel Corp.), Box 609, 1342 - 28th St., Columbus, Nebr.
91737	Gremar Mfg. Co., Wakefield, Mass.
91755	Harrison & Bonini, 1122 Harrison St., San Francisco, California
91827	K & F Tool Die & Mfg. , Inc., 1203 Dell Ave., Campbell, California
93332	Sylvania Electric Products, Inc., Semiconductor Div., 100 Sylvan Rd., Woburn, Mass.
93389	Proto Stamping, Washington & Santa Fe, Los Angeles 54, Calif.
94144	Raytheon, 465 Centre St., Quincy, Mass. 02164
94375	Automatic Metal Products Corp., 323 Berry St., Brooklyn 11, N.Y.
95263	Leecraft Mfg. Co., Inc., 44-35 - 21st St., Dept. E., Long Island City, N.Y.
95354	Methode Electronics, Inc., 7447 W. Wilson Ave., Chicago, Ill.
95987	Weckesser Co., Inc., 4444 W. Irving Park, Chicago, Ill.
96214	Texas Instruments, Inc., Semiconductor-Components Div., Box 5012, Dallas, Texas
96791	Borg Electronics, Div., Amphenol-Borg Electronics Corp., 120 S. Main St., Janesville, Wisc.
97464	Industrial Retaining Ring Co., 57 Cordier St., Irvington, N.J.
99120	Plastic Capacitors, Inc., 2620 N. Clybourn Ave., Chicago, Ill.
99313	Varian, 611 Hansen Way, Palo Alto, California (BWO)
99942	Hoffman Electronics Corp., Semiconductor Div., Box 471, El Monte, California

SECTION 6 - PARTS LIST

MAIN CHASSIS AND PC BOARD ASSEMBLIES

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	SCHEMATIC DIAGRAM
		Main Chassis	D900845
A1	950813	Cathode Supply PC Board	C900770
A2	950818	Low Voltage Supply PC Board	C900766
A3	951045	Sweep PC Board	C900887
A4	950911	Markers PC Board	C900733
A5	950619	Modulator PC Board	C900714
A6	951096	Auxiliary Supply PC Board	C900909
A7	901315	Helix Overcurrent PC Board	C900843
A9	950635	Transfer Oscillator PC Board	C900747
A10	951083	Series Regulator PC Board	C900906
A11	950621	Grid-Leveled Leveler Amplifier PC Board	C900730
$A11_1$	901505-1	Grid-Leveled Circuit Interconnection Module	C900872
A11	951088	PIN Diode Leveler Amplifier PC Board	D900933
$A11_{PS}$	951087	PIN Diode Leveler Power Supply Board	B900930††
$A11_2$	901504	PIN Diode Leveler Control Circuit Interconnection Module	C907055
A12	901488	Elevated Supply PC Board	C900869
A13	950641	Diode Shaper PC Board	C900713
A14	951137	Filament Protection PC Board	C900910
A15	951061	Rectifier Assembly PC Board	B900905
A19	951155	[v] Anode Protection PC Board	B900940
A25	901504	H. V. Feedback PC Board	D900845†
A26	951249	Bleeder Assembly PC Board	C900955
		TABLE OF MICROWAVE COMPONENTS	

† included on schematic indicated †† included on apron of schematic C907055

[v] Used with Varian tubes only

MODEL 6400 MAIN CHASSIS

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		CAPACITORS		
C1	13-54	Fixed, elect., 80/50 µf, 150 v	56289	TVL 2442.1
C2	13-38	Fixed, elect., 100 µf, 250 v	56289	TVL 1535
C3	13-46	Fixed, elect., 150 µf/150 v, 100 µf, 50 v	09023	XBO 575.5
C4 and C5	15-21	Capacitor, fixed, paper, 2 µf, 2Kv	20286	CB 202A205B
C6 and C7		Not used		
C8	13-61	Fixed, elect., 50/50 µf, 450 v		
C9	13-53	Fixed, elect., 200/200 µf, 150 v	56289	TVL 2447
C10	13-9	Fixed, elect., 3000 µf, 15 v	37942	WPO 42A
C11		Same as C2		
C12	13-36	Fixed, elect., 100/100 µf, 50 v	56289	TVL 2326
C13	13-35	Fixed, elect., 500 µf, 25 v	56289	TVL 1220
C14	14-10 (or 14-46)	Fixed, paper, 0.005 µf, 6Kv	09023 (or 00656)	PKM 60D5 or B161Y26
C15		Not used		
C16		Same as C14		
C17 thru C23	12-28	.001 µf, fixed, ceramic, 6 Kv	71590	DD60-102
C24	12-30	Fixed, ceramic, 1.5 pf, 6Kv	56289	60-GA-V15
		LAMPS		
DS1 and DS2	126-9	Panel	95263	32-1111T
DS3	126-1	Neon	08806	NE-2
		FUSES		
F1	121-23	1.2 amp, Type 3AG, Slo-blo	75915	31301.2
F2	121-26	3 amp., Type 3AG, Slo-blo	75915	313003
F3	121-14	2 amp, Type 3AG, Slo-blo	75915	313002
J1 thru J6	133-63	KZ 22S	81312	KZ 22S
J7	133-62	KZ 10S	81312	KZ 10S
J8 thru J12	131-UG/1094	Type BNC, UG-1094	94375	UG 1094/U
J13	133-13	M4S-LRN	81312	M4S-LRN
J14 thru J34		Not used		
J35		Same as J8		
J36	133-10	M9S-LRN	81312	M9S-LRN
J37		Same as J8		
J38 and J39		Not used		
P40	133-25	PM6P (supplied with BWO)	81312	PM6P
J40	133-8	PM6S	81312	PM6S
P41	133-16	SMI-12 (supplied with BWO)	81312	SMI-12
J40	133-7	SMI-6	81312	SMI-6
		RELAYS		
K1	106-25	Time Delay, 6N060T	70563	6N060T
K2 and K3	106-30	100 VDC, KA 1466-1	77342	KA 1466-1
K4	106-24	P & B, RS5D-10K	77342	RS5D-10K
		METERS		
M1	87-3	Elapsed time	03782	87-3
		TRANSISTORS		
Q1	81-89	2N1537/2N4903	04713	2N1537/2N4903
Q2	81-112	40251	07029	40251
Q3 and Q4	81-86	2N2147	07029	2N2147
Q5		Same as Q2		

MAIN CHASSIS ASSEMBLY (con'd)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		RESISTORS		
R1		Not used		
R2	41-10 Ω	Fixed, comp., 10 Ω, 1/2 w, 10%	01121	EB 1001
R3	41-100K	Fixed, comp., 100K, 1/2 w, 10%	01121	EB 1041
R4		Not used		
R5	43-68K	Fixed, comp., 68K, 2 w, 10%	01121	HB 6831
R6		Same as R3		
R7	41-10K	Fixed, comp., 10K, 1/2 w, 10%	01121	EB 1031
R8	41-15K	Fixed, comp., 15K, 1/2 w, 10%	01121	EB 1531
R9		Same as R7		
R10 thru R27		Not used		
R28	41-150K	Fixed, comp., 150K, 1/2 w, 10%	01121	EB 1541
R29	41-27 Ω	Fixed, comp., 27 Ω, 1/2 w, 10%	01121	EB 2701
R30	102-121	Variable, 5M, 1/2 w, 1%	71450	C 21845
R31	56-374K	Fixed, MF, 374K, 1/2 w, 1%	19701	MF-7C-TO-374K
R32	41-10K	Fixed, comp., 10K, 1/2 w, 10%	01121	EB 1031
R33	63-13	Fixed, WW, 2.5K, 5 w, 10%	44655	4633
R34	102-139	Variable, 10K (part of S15/S17)		
R35	41-1K	Fixed, comp., 1K, 1/2 w, 10%	01121	EB 1031
R36 (Part of S12)	102-135	Variable, 10K (S/N 90 and up) Part of S12 Variable, 100K (S/N 1-89)		
R37	71-124	Variable, 10K (part of S8)		
R38	74-6	Variable, 1K, 10 turn, 1%,	21030	7216RL1-KL.25
R39 and R40	41-33 Ω	Fixed, comp., 33 Ω, 1/2 w, 10%	01121	EB 3301
R41		Same as R38		
R42	71-72	Variable, 100 Ω, 5 w, 10%	71450	AW-100 Ω
R43		Same as R39		
R44		Same as R38		
R45		Same as R39		
R46		Same as R38		
R47		Same as R39		
R48		Same as R38		
R49 thru R62		Not used		
R63		Same as R3		
R64 and R65	41-470K	Fixed, comp., 470K, 1/2 w, 10%	01121	EB 4741
R66 thru R70		Not used		
R71 thru R75	71-102	Resistor, variable, 100 Ω	71450	XHT-201-100 Ω
R76		Not used		
R77	41-100 Ω	Fixed, comp., 100 Ω, 1/2 w, 10%	01121	EB 1011
R78	41-82K	Fixed, comp., 82K, 1/2 w, 10%	01121	EB 8231
R79		Not used		
R80 thru R85	52-464K	Fixed, MF, 464K, 1 w, 1%	19701	MFS-1-T2-464K
R86	62-1	Fixed, WW, 10K, 10 w, 5%	35434	C10-10K
R87	71-122	Variable, 2.5K, 3 w, 30%		
R88 and R89		Not used		
R90		Same as R87		
R91	41-1K	Fixed, comp., 1K, 1/2w, 10%	01121	EB 1021
R92		Not used in S/N 56 & up		
	41-10K	Fixed, comp., 10K, 1/2 w, 10% (in S/N 1 - 55; connected in parallel with R36 when 100K value is used for R36)	01121	EB 1031
R93 thru R96	41-4.7M	Fixed, comp., 4.7M, 1/2 w, 10%	01121	EB 4751
R97	56-69.8K	Fixed, MF, 69.8K, 1/2 w, 1%	19701	MF-7C-TO-69.8K

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		SWITCHES		
S1	101-3	Toggle, DPST	04009	81024GB
S2		Not used		
S3	102-128	Lever, 115-220 line	76854	233-785-187-53F1-1SSA
S4	101-8	Pushbutton, (N.C.)	81073	2202
S5 and S6	101-17	Interlock	01963	E33-20A
S7	101-19	Pushbutton	82389	263
S8	71-124	DPDT, rear, dual shaft (Part of R37)		
S9	101-18	Pushbutton (Switchcraft 201)	82382	201
S10	102-122	Rotary 630905	03782	630905 (102-122)
S11	101-121	Rotary 630903	03782	630903 (102-121)
S12	102-135	Rotary (with 10K pot. R36)	03782	102-135
S13 and S14	102-138	Rotary 650914	03782	650914 (102-138)
S15	102-139	Rotary (part of S17/R34)	03782	102-139
S16	102-136	Slide, blanking	76854	399278-278
S17	(102-139)	DPDT (part of S15/R34)	03782	102-139
S18	102-136	Slide, blanking	76854	399278-278
		TRANSFORMERS		
T1	91-195	Power AE C950601	03782	91-195 (C950601)
T2	91-196	Power AE C950611	03782	91-196 (C950611)
		FUSES HOLDERS		
XF1	122-2	Fuse holder	75915	357001
XF2	122-1	Fuse holder, clip-on type	75915	342004
XF3		Same as XF1		
		RELAY SOCKETS		
XK1	136-19	9 pin, miniature	95354	S161-125-PB
		TRANSISTOR SOCKETS		
XQ1 thru XQ5	136-27	Transistor	71785	2TS1

A25 HIGH VOLTAGE FEEDBACK RESISTOR BOARD

For A25R1 - A25R6 see R80 - R85 listed under Main Chassis Assembly.

For A25C1 see C24 listed under Main Chassis Assembly.

The items on the A25 board are identical to those Main Chassis items indicated; only the reference designators are changed in units containing A25.

CATHODE SUPPLY PC BOARD A1 (Assy. 950813)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		CAPACITORS		
A1C1 and A1C2	12-3	0.01 mf, fixed, ceramic, 500 v	71590	DD-1032
A1C3	12-2	0.001 mf, fixed, ceramic, 500 v	71982	851-X5R-102K
A1C4	12-15	.002 µf, fixed, ceramic, 1Kv	71590	DD 202
A1C5	12-9	0.05 mf, fixed, ceramic, 75 v	71590	DDA-503
A1C6**	12-15	0.002 mf, fixed, ceramic, 500 v	71590	DD-202
A1C7**	12-34	0.1 mf, fixed, ceramic, 100 v	91418	BT 010
A1C8 and A1C9		Same as A1C1		
A1C10	12-27	270 pf, fixed, ceramic, 500 v	71590	DD 271
A1C11	14-13	1µf, fixed, paper	00656	P8292ZN13
A1C12 and A1C13		Same as A1C7		
A1C14**	12-22	100 pf, fixed, ceramic, 1Kv	71982	831-X5R-101K
A1C15	13-33	10 mf, fixed, elect., 200 v	56289	TE 1407
		DIODES		
A1CR1	81-88	1N3041A	04713	1N3041A
A1CR2 and A1CR3	81-20	D1-46/1N4385	12060	D1-46
A1CR4	81-77	1N7652A; Alt. PSI 18199	99942	1N752A
A1CR5 thru A1CR7	81-132	1N914 (installed as required)	07263	1N914
		TRANSISTORS		
A1Q1	81-113	2N4956/NS7301	07263/27014	2N4956/NS7301
A1Q2 thru A1Q5	81-188	2N3643/2N3646/S18563	07263	2N3643
A1Q6 and A1Q7	81-72	2N699	96214	2N699
A1Q8 and A1Q9	81-115	2N3565	07263	2N3565
A1Q10 and A1Q11		Same as A1Q1		
A1Q12 and A1Q13	81-114	2N3638A	07263	2N3638A
		RESISTORS		
A1R1	41-15K	15K, fixed, comp., 1/2 w, 10%	01121	EB 1531
A1R2	41-33K	33K, fixed, comp., 1/2 w, 10%	01121	EB 3331
A1R3 thru A1R5	57-15K	15K, fixed, MF, 1/2 w, 1/2%	75042	CEC-TO-15K
A1R6	56-14.7K	14.7K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-14.7K
A1R7	41-22K	22K, fixed, comp., 1/2 w, 10%	01121	EB 2231
A1R8	41-470 Ω	470 Ω, fixed, comp., 1/2 w, 10%	01121	EB 7411
A1R9	41-15K	15K, fixed, comp., 1/2 w, 10%	01121	EB 1531
A1R10		Same as A1R7		
A1R11	41-2.2K	2.2K, fixed, comp., 1/2 w, 10%	01121	EB 2221
A1R12*	41-330 Ω	330 Ω, fixed, comp., 1/2 w, 10%	01121	EB 3311
A1R13	41-3.9K	3.9K, fixed, comp., 1/2 w, 10%	01121	EB 3921
A1R14		Same as A1R11		
A1R15*	41-47 Ω	47 Ω, factory select, nominal value	01121	EB 4701
A1R16	41-1.2K	1.2K, fixed, comp., 1/2 w, 10%	01121	EB 1221
A1R17	41-27K	27K, fixed, comp., 1/2 w, 10%	01121	EB 2731
A1R18	43-3.9K	3.9K, fixed, comp., 2 w, 10%	01121	HB 3921
A1R19	42-4.7K	4.7K, fixed, comp., 1 w, 10%	01121	GB 4721
A1R20	41-100Ω	100 Ω, fixed, comp., 1/2 w, 10%	01121	EB 1011
A1R21	56-392K	221K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-392K
A1R22	56-221K	221K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO221K
A1R23	41-47K	47K, fixed, comp., 1/2 w, 10%	01121	EB 4731
A1R24	71-94	20 turn, variable, 5K	21030	79PR5K
A1R25	41-100K	100K, fixed, comp., 1/2 w, 10%	01121	EB 1041
A1R26	41-10K	10K, fixed, comp., 1/2 w, 10%	01121	EB 1031
A1R27	41-4.7K	4.7K, fixed, comp., 1/2 w, 10%	01121	EB 4721
A1R28	41-1K	1K, fixed, comp., 1/2 w, 10%	01121	EB 4721
A1R29 and A1R30	56-4.99K	4.99K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-4.99K
A1R31	41-1.5K	1.5K, fixed, comp., 1/2 w, 10%	01121	EB 1521
A1R32		Same as A1R7		
A1R33		Same as A1R26		
A1R34	35-6.8K	6.8K, fixed, MF, 2 w, 5%	01121	CB 6821
A1R35		Same as A1R31		
A1R36		Same as A1R7		
A1R37		Same as A1R26		
A1R38	71-91	500 Ω, variable, 20 turn	21030	79PR500

LOW VOLTAGE SUPPLY PC BOARD A2 (Assy. 950818)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		CAPACITORS		
A2C1 thru A2C5	14-30	0.1 µf, fixed, mylar, 100v	72136	1MDF-3-104
A2C6	12-3	.01 mf, fixed, ceramic, 500 v	71590	DD-1032
A2C7	13-40	100 mf, fixed, elect., 10 v	56289	TE 1119.3
A2C8	13-33	10 mf, fixed, elect., 100 v	56289	TE 1407
A2C9		Same as A2C1		
A2C10		Same as A2C6		
		DIODES		
A2CR1	81-75	1N823	04713	1N823
A2CR2 and A2CR3	81-41	1N459	93332	1N459
		TRANSISTORS		
A2Q1	81-71	2N697	96214	2N697
A2Q2 and A2Q3	81-114	2N3638A	07263	2N3638A
A2Q4	81-113	2N4956/NS7301	07263/27014	2N4956/NS7301
A2Q5 thru A2Q7		Same as A2Q3		
A2Q8		Same as A2Q4		
A2Q9 and A2Q10		Same as A2Q2		
A2Q11		Same as A2Q1		
A2Q12		Same as A2Q3		
A2Q13	81-115	2N3565	07263	2N3565
		RESISTORS		
A2R1	41-100 Ω	100 Ω, fixed, comp., 1/2 w, 10%	01121	EB 1011
A2R2	43-10K	10K, fixed, comp., 2 w, 10%	01121	HB 1031
A2R3	41-15K	15K, fixed, comp., 1/2 w, 10%	01121	EB 1531
A2R4	56-19.6K	19.6K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-19.6K
A2R5	44-1 Ω	1 Ω, fixed, WW, 1/2 w, 5%	75042	BWH-1Ω
A2R6 and A2R7		Same as A2R4		
A2R8	41-22 Ω	22 Ω, fixed, comp., 1/2 w, 10%	01121	EB 2201
A2R9	71-90	200 Ω, variable, 20 turn, WW	21030	79PR200
A2R10 and A2R11	56-1.21K	1.21K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-1.21K
A2R12		Same as A2R5		
A2R13	41-1.5K	1.5K, fixed, comp., 1/2 w, 10%	01121	EB 1521
A2R14	41-8.2K	8.2K, fixed, comp., 1/2 w, 10%	01121	EB 8221
A2R15		Same as A2R3		
A2R16	41-820 Ω	820 Ω, fixed, comp., 1/2 w, 10%	01121	EB 8211
A2R17	56-750 Ω	750 Ω, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-750K
A2R18		Same as A2R9		
A2R19		Same as A2R10		
A2R20 thru A2R22		Same as A2R4		
A2R23	41-330 Ω	330 Ω, fixed, comp., 1/2 w, 10%	01121	EB 3311
A2R24		Same as A2R10		
A2R25	41-33K	33K, fixed, comp., 1/2 w, 10%	01121	EB 3331
A2R26		Same as A2R3		
A2R27	56-4.99K	4.99K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-4.99K
A2R28	56-34K	34K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-34K
A2R29 and A2R30	41-470 Ω	470 Ω, fixed, comp., 1/2 w, 10%	01121	EB 4711
A2R31	56-15K	15K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-15K
A2R32	56-49.9K	49.9K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-49.9K
A2R33		Same as A2R1		
A2R34*	41-10 Ω	10 Ω, fixed, comp., 1/2 w, 10%	01121	EB 1031
A2R35	41-5.6K	5.6K, fixed, comp., 1/2 w, 10%	01121	EB 5621
A2R36		Same as A2R29		
A2R37		Same as A2R1		
A2R38	41-1.2K	1.2K, fixed, comp., 1/2 w, 10%	01121	EB 1221
A2R39		Same as A2R3		
A2R40	41-2.2K	2.2K, fixed, comp., 1/2 w, 10%	01121	EB 2221
A2R41* and A2R42*	41-3.3K	3.3K, fixed, comp., 1/2 w, 10%	01121	EB 3321

*Factory Select
** installed at factory option

SWEEP PC BOARD A3 (Assy. 951045)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		CAPACITORS		
A3C1	12-2	0.001 mf, fixed, ceramic, 500 v	71982	851-X5R-102K
A3C2	12-3	0.01 mf, fixed, ceramic, 500 v	71590	DD-1032
A3C3 and A3C4		Same as A3C1		
A3C5 thru A3C7		Same as A3C2		
A3C8	12-24	390 pf, fixed, ceramic, 500 v	71982	831-X5R-391K
A3C9		Same as A3C1		
A3C10	12-31	0.002 mf, fixed, ceramic, 500 v	56289	5-GAB-S23
A3C11	12-18	200 pf, fixed, ceramic, 500 v	71982	831-X5R-201K
A3C12		Same as A3C2		
A3C13		Same as A3C1		
		DIODES		
A3CR1 thru A3CR8	81-41	1N459	93332	1N459
A3Q1 and A3Q2	81-115	2N3565	07263	2N3565
A3Q3	81-71	2N697	96214	2N697
A3Q4		Same as A3Q1		
A3Q5	81-73	2N706	07029	2N706
A3Q6	81-114	2N3638A	07263	2N3638A
A3Q7	81-72	2N699	96214	2N699
A3Q8 and A3Q9	81-116	2N3646/S18563	07263	2N3646
A3Q10 and A3Q11		Same as A3Q6		
A3Q12 and A3Q13		Same as A3Q9		
A3Q14		Same as A3Q1		
A3Q15	81-117	2N3440	07029	2N3440
A3Q16		Same as A3Q1		

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		RESISTORS		
A3R1	41-220K	220K, fixed, comp., 1/2 w, 10%	01121	EB 2241
A3R2	41-33K	33K, fixed, comp., 1/2 w, 10%	01121	EB 3331
A3R3	41-2.2K	2.2K, fixed, comp., 1/2 w, 10%	01121	EB 2221
A3R4	41-3.3K	3.3K, fixed, comp., 1/2 w, 10%	01121	EB 3321
A3R5		Same as A3R2		
A3R6		Same as A3R1		
A3R7	56-4.99K	4.99K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-4.99K
A3R8	56-12.1K	12.1K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-12.1K
A3R9	41-27K	27K, fixed, comp., 1/2 w, 10%	01121	EB 2231
A3R10	41-100 K	100K, fixed, comp., 1/2 w, 10%	01121	EB 1041
A3R11	41-22K	22K, fixed, comp., 1/2 w, 10%	01121	EB 2231
A3R12	41-15K	15K, fixed, comp., 1/2 w, 10%	01121	EB 1531
A3R13		Same as A3R2		
A3R14	41-1.8M	1.8M, fixed, comp., 1/2 w, 10%	01121	EB 1851
A3R15	41-100 Ω	100 Ω, fixed, comp., 1/2 w, 10%	01121	EB 1011
A3R16	41-8.2K,	8.2K, fixed, comp., 1/2 w, 10%	01121	EB 8221
A3R17	41-39K	39K, fixed, comp., 1/2 w, 10%	01121	EB 3931
A3R18	41-470K	470K, fixed, comp., 1/2 w, 10%	01121	EB 4711
A3R19		Same as A3R10		
A3R20	41-4.7K	4.7K, fixed, comp., 1/2 w, 10%	01121	EB 4721
A3R21	41-56K	56K, fixed, comp., 1/2 w, 10%	01121	EB 5631
A3R22	41-120K	120K, fixed, comp., 1/2 w, 10%	01121	EB 1241
A3R23		Same as A3R10		
A3R24		Same as A3R18		
A3R25		Same as A3R4		
A3R26	41-5.6K	5.6K, fixed, comp., 1/2 w, 10%	01121	EB 5621
A3R27		Same as A3R10		
A3R28	41-15M	15M, fixed, comp., 1/2 w, 10%	01121	EB 1561
A3R29 and A3R30	41-10K	10K, fixed, comp., 1/2 w, 10%	01121	EB 1031
A3R31		Same as A3R11		
A3R32		Same as A3R9		
A3R33		Same as A3R10		
A3R34		Same as A3R4		
A3R35		Same as A3R2		
A3R36		Same as A3R3		
A3R37	41-1K	1K, fixed, comp., 1/2 w, 10%	01121	EB 1021
A3R38		Same as A3R4		
A3R39		Same as A3R1		
A3R40	41-180K	180K, fixed, comp., 1/2 w, 10%	01121	EB 1841
A3R41		Same as A3R15		
A3R42	41-1.8K	1.8K, fixed, comp., 1/2 w, 10%	01121	EB 1821
A3R43	41-22 Ω	22 Ω, fixed, comp., 1/2 w, 10%	01121	EB 2201
A3R44	41-270 Ω	270 Ω, fixed, comp., 1/2 w, 10%	01121	EB 2711
A3R45		Same as A3R17		

MARKERS PC BOARD A4 (Assy. 950911)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		CAPACITORS		
A4C1	12-9	0.05 mf, fixed, ceramic, 75 v	71590	DDA-503
A4C2	12-21	27 pf, fixed, ceramic, 500 v	71982	831-UZM-270K
A4C3		Same as A4C1		
A4C4		Same as A4C2		
A4C5		Same as A4C1		
A4C6		Same as A4C2		
		DIODES		
A4CR1 thru A4CR13	81-41	Diode, 1N459	93332	1N459
		TRANSISTORS		
A4Q1 and A4Q2	81-90 or 81-115	S6793 or 2N3565	07263	S6793 or 2N3565
A4Q3	81-114	2N3638A	07263	2N3638A
A4Q4	81-51	2N404	07029	2N404
A4Q5 and A4Q6		Same as A4Q3		
A4Q7 and A4Q8		Same as A4Q1		
A4Q9		Same as A4Q3		
A4Q10		Same as A4Q4		
A4Q11 and A4Q12		Same as A4Q3		
A4Q13 and A4Q14		Same as A4Q1		
A4Q15		Same as A4Q3		
A4Q16		Same as A4Q4		
A4Q17 thru A4Q19		Same as A4Q4		
		RESISTORS		
A4R1	41-100K	100K, fixed, comp., 1/2 w, 10%	01121	EB 1041
A4R2		Not used		
A4R3 thru A4R5	56-100K	100K, fixed, MF, 1/2 w, 1/2%	19701	MF-7C-TO-100K
A4R6	56-4.64K	4.64K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-4.64K
A4R6**	41-5.6K	5.6K, fixed, comp., 1/2 w, 10%	01121	EB 5621
A4R7	41-94	5K, variable	21030	79PR5K
A4R8	41-1M	1M, fixed, comp., 1/2 w, 10%	01121	EB 1051
A4R9	56-2.87K	2.87K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-2.87K
A4R9**	41-2.7K	2.7K, fixed, comp., 1/2 w, 10%	01121	EB 2721
A4R10		Same as A4R8		
A4R11	41-68K	68K, fixed, comp., 1/2 w, 10%	01121	EB 6831
A4R12	41-1K	1K, fixed, comp., 1/2 w, 10%	01121	EB 1021
A4R13	41-4.7K	4.7K, fixed, comp., 1/2 w, 10%	01121	EB 4721
A4R14	41-10K	10K, fixed, comp., 1/2 w, 10%	01121	EB 1031
A4R15	41-47 Ω	47 Ω, fixed, comp., 1/2 w, 10%	01121	EB 4701
A4R16 and A4R17		Same as A4R8		
A4R18		Same as A4R12		
A4R19	41-180K	180K, fixed, comp., 1/2 w, 10%	01121	EB 180K
A4R20	56-10K	10K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-10K
A4R21	56-4.99K	4.99K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-4.99K
A4R22		Same as A4R20		
A4R23	41-33K	33K, fixed, comp., 1/2 w, 10%	01121	EB 3331
A4R24		Same as A4R12		
A4R25		Not used		
A4R26		Same as A4R20		
A4R27		Not used		
A4R28 thru A4R30		Same as A4R3		
A4R31		Same as A4R8		
A4R32		Same as A4R7		
A4R33		Same as A4R8		
A4R34		Same as A4R11		
A4R35		Same as A4R12		
A4R36		Same as A4R13		
A4R37		Same as A4R14		
A4R38		Same as A4R15		
A4R39		Same as A4R8		
A4R40		Same as A4R12		
A4R41		Same as A4R13		
A4R42		Same as A4R19		
A4R43		Same as A4R20		
A4R44		Same as A4R21		
A4R45		Same as A4R20		
A4R46		Same as A4R23		
A4R47		Same as A4R12		
A4R48	41-2.2K	2.2K, fixed, comp., 1/2w, 10%	01121	EB 2221
A4R49		Same as A4R20		
A4R50		Not used		
A4R51 thru A4R53		Same as A4R3		
A4R54		Same as A4R8		
A4R55		Same as A4R7		
A4R56		Same as A4R8		
A4R57		Same as A4R11		
A4R58		Same as A4R12		
A4R59		Same as A4R13		
A4R60		Same as A4R14		
A4R61		Same as A4R15		
A4R62		Same as A4R8		
A4R63		Same as A4R12		
A4R64		Same as A4R13		
A4R65		Same as A4R19		
A4R66		Same as A4R20		
A4R67		Same as A4R21		
A4R68		Same as A4R20		
A4R69		Same as A4R23		
A4R70		Same as A4R12		
A4R71		Not used		
A4R72		Same as A4R20		
A4R73		Same as A4R23		
A4R74		Same as A4R14		
A4R75	41-82K	82K, fixed, comp., 1/2 w, 10%	01121	EB 8231
A4R76		Same as A4R12		
A4R77		Same as A4R75		

** Alternate values of A4R6 and A4R9 must be used together.

MODULATOR PC BOARD A5 (Assy. 950619)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		CAPACITORS		
A5C1	14-31	0.047 mf, fixed, mylar, 2%, 200 v	77557	VT 103 H2A
A5C2	12-2	0.001 mf, fixed, ceramic, 500 v	71982	811-102
A5C3	12-18	200 pf, fixed, ceramic, 500 v	71982	831-X5R-201K
A5C4 and A5C5	12-22	100 pf, fixed, ceramic, 500 v	71982	831-X5R-101K
A5C6		Same as A5C2		
A5C7	13-49	50 µf, fixed, elect., 25 v	56289	TE 1209
A5C8 and A5C9	12-34	0.1 µf, fixed, ceramic, 100 v	91418	BT 010
		DIODES		
A5CR1 thru A5CR5	81-41	1N459	93332	1N459
		TRANSISTORS		
A5Q1	81-104	2N1671B	33173	2N1671B
A5Q2	81-116	2N3646 (S/N 115 & below)	07263	2N3646
	81-115	2N3565 (S/N 116 & above)	07263	2N3565
A5Q3 and A5Q4	81-116	2N3646 (S/N 115 & below)	07263	2N3646
	81-188	2N3643 (S/N 116 & above)	07263	2N3643
A5Q5 and A5Q6	81-116	2N3646	07263	2N3646
A5Q7	81-114	2N3638A	07263	2N3638A
A5Q8	81-71	2N697	96214	2N697
		RESISTORS		
A5R1 thru A5R2	41-12K	12K, fixed, comp., 1/2 w, 10% (S/N 10 & below)	01121	EB 1231
	41-10K	10K, factory selected nominal value, 1/2 w, 10% (S/N 11 & up)	01121	EB 1031
A5R3	41-330 Ω	330 Ω, fixed, comp., 1/2 w, 10%	01121	EB 3311
A5R4	41-100 Ω	100 Ω, fixed, comp., 1/2w, 10%	01121	EB 1011
A5R5	41-4.7K	4.7K, fixed, comp., 1/2w, 10%	01121	EB 4721
A5R6 thru A5R8	41-10K	10K, fixed, comp., 1/2 w, 10%	01121	EB 1031
A5R9	41-22K	22K, fixed, comp., 1/2 w, 10%	01121	EB 2231
A5R10	41-2.2K	2.2K, fixed, comp., 1/2 w, 10%	01121	EB 2221
A5R11	41-220 Ω	220 Ω, fixed, comp., 1/2 w, 10%	01121	EB 2211
A5R12		Same as A5R9		
A5R13		Same as A5R10		
A5R14		Same as A5R11		
A5R15		Same as A5R10		
A5R16 and A5R17	56-7.50K	7.50K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-7.5K
A5R18		Not used		
A5R19		Same as A5R10		
A5R20	42-2.2K	2.2K, fixed, comp., 1 w, 10%	01121	GB 2221
A5R21		Same as A5R9		
A5R22		Same as A5R5		
A5R23 and A5R24	41-220K	220K, fixed, comp., 1/2 w, 10%	01121	EB 2241
A5R25	41-1K	1K, fixed, comp., 1/2 w, 10%	01121	EB 1021
A5R26 and A5R27		Same as A5R16		
A5R28	41-5.6K	5.6K, fixed, comp., 1/2 w, 10%	01121	EB 5621
A5R29	41-33K	33K, fixed, comp., 1/2 w, 10%	01121	EB 3331
A5R30	41-1.8K	1.8K, fixed, comp., 1/2 w, 10%	01121	EB 1821
A5R31 and A5R32	41-820 Ω	820 Ω, fixed, comp., 1/2 w, 10%	01121	EB 8211

AUXILIARY SUPPLY PC BOARD A6 (Assy. 951096)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		CAPACITORS		
A6C1	13-33	10 mf, fixed, elect., 100 v	56289	TE 1407
A6C2	13-40	100 mf, fixed, elect., 10 v	56289	TE 1119.3
A6C3	12-34	0.1 mf, fixed, ceramic, 100 v	91418	BT 010
A6C4	12-3	0.01 mf, fixed, ceramic, 500 v	71590	DD-1032
A6C5	14-21	0.1 mf, fixed, paper, 400 v	09023	WMF-4PIE
		DIODES		
A6CR1	81-20	1N4385/D1-46	76433	1N4385
A6CR2	81-75	1N823	04713	1N823
A6CR3 and A6CR4	81-146	1N752A/PSI 18199	12060	1N752A
A6CR5	81-41	1N459	93332	1N459
A6CR6		Not used		
A6CR7 thru A6CR9		Same as A6CR5		
A6CR10		Same as A6CR3		
		LAMPS		
A6DS1	126-1	Neon, NE-2	08806	NE-2
		RELAYS		
A6K1	106-29	RS5D-6VDC	77342	RS5D-6VDC
		TRANSISTORS		
A6Q1	81-133 or	40372 or		40372 or
	81-203	40373	07029	40373
A6Q2 thru A6Q5	81-71	2N697	96214	2N697
A6Q6	81-114	2N3638A	07263	2N3638A
A6Q7	81-116	2N3646	07263	2N3646
A6Q8		Same as A6Q2		
A6Q9	81-181	2N4889	07263	2N4889
A6Q10 and A6Q11	81-115	2N3565	07263	2N3565
		RESISTORS		
A6R1	42-15 Ω	15 Ω, fixed, comp., 1 w, 10%	01121	GB 1501
A6R2	41-5.6K	5.6K, fixed, comp., 1/2 w, 10%	01121	EB 5621
A6R3	43-8.2K	8.2K, fixed, comp., 2 w, 10%	01121	HB 8221
A6R4	56-1K	1K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-1K
A6R5	71-98	200 Ω, variable	71450	#115-200 Ω
A6R6 and A6R7	56-8.25K	8.25K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-8.25K
A6R8	41-100 Ω	100 Ω, fixed, comp., 1/2 w, 10%	01121	EB 1011
A6R9	41-6.8K	6.8K, fixed, comp., 1/2 w, 10%	01121	EB 6821
A6R10	41-82K	82K, fixed, comp., 1/2 w, 10%	01121	EB 8231
A6R11	41-22 Ω	22 Ω, fixed, comp., 1/2 w, 10%	01121	EB 2201
A6R12		Same as A6R9		
A6R13	41-330 Ω	330 Ω, fixed, comp., 1/2 w, 10%	01121	EB 3301
A6R14 and A6R15		Same as A6R6		
A6R16	43-82 Ω	82 Ω, fixed, comp., 2 w, 10%	01121	HB 8201
A6R17		Not used		
A6R18	41-390 Ω	390 Ω, fixed, comp., 1/2 w, 10%	01121	EB 3911
A6R19		Not used		
A6R20	41-220 Ω	220 Ω, fixed, comp., 1/2 w, 10%	01121	EB 2211
A6R21	71-99	100 Ω, variable,	71450	#115-100 Ω
A6R22	42-100 Ω	100 Ω, fixed, comp., 1 w, 10%	01121	GB 1011
A6R23	41-470 Ω	470 Ω, fixed, comp., 1/2 w, 10%	01121	EB 4711
A6R24		Not used		
A6R25	41-100K	100K, fixed, comp., 1/2 w, 10%	01121	EB 1041
A6R26	56-31.6K	31.6K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-31.6K
A6R27	56-1.69K	1.69K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-1.69K
A6R28	41-4.7K	4.7K, fixed, comp., 1/2 w, 10%	01121	EB 4721
A6R29	41-220K	220K, fixed, comp., 1/2 w, 10%	01121	EB 2211
A6R30	41-2.2K	2.2K, fixed, comp., 1/2 w, 10%	01121	EB 2221
A6R31	41-270 Ω	270 Ω, fixed, comp., 1/2 w, 10%	01121	EB 2711
A6R32		Same as A6R20		

HELIX OVERCURRENT PC BOARD A7 (Assy. 901315)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		CAPACITORS		
A7C1	14-23	10 µf, fixed, paper, 2%, 200 v	18489	VMT 106 H2A
A7C2	14-24	1 µf, fixed, paper, 2%, 200 v	18489	VT 105 H2A
A7C3	14-25	0.1 µf, fixed, paper, 2%, 200 v	18489	VT 104 H2A
A7C4	14-26	0.01 µf, fixed, paper, 2%, 200 v	18489	VT 103 H2A
		DIODES		
A7CR1	81-41	1N459	93332	1N459
		RELAYS		
A7K1	106-24	SPDT, 10K Ω, Coil	77342	RS59-10K
		TRANSISTORS		
A7Q1	81-71	2N697	96214	2N697
A7Q2 and A7Q3	81-114	2N3638A	07263	2N3638A
A7Q4	81-129	2N3645	07263	2N3645
A7Q5	81-72	2N699	96214	2N699
A7Q6	81-115	2N3565	07263	2N3565
		RESISTORS		
A7R1	41-1K	1K, fixed, comp., 1/2 w, 10%	01121	EB 1021
A7R2	56-1.62K	1.62K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-1.62K
A7R3	71-90	200 Ω, variable	21030	79PR200
A7R4	56-1K	1K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-1K
A7R5		Same as A7R3		
A7R6	41-6.8K	6.8K, fixed, comp., 1/2 w, 10%	01121	EB 6821
A7R7	43-8.2K	8.2K, fixed, comp., 2 w, 10%	01121	HB 8221
A7R8	43-3.9K	3.9K, fixed, comp., 2 w, 10%	01121	HB 3921
A7R9	56-18.7K	18.7K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-18.7K
A7R10	56-49.9 Ω	49.9 Ω, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-49.9 Ω
A7R11	56-866 Ω	866 Ω, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-866 Ω
A7R12	56-1.78K	1.78K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-1.78K
A7R13 and A7R14		Same as A7R16		
A7R15	41-10K	10K, fixed, comp., 1/2 w, 10%	01121	EB 1031
A7R16	41-56K	56K, fixed, comp., 1/2 w, 10%	01121	EB 5631
A7R17	41-4.7K	4.7K, fixed, comp., 1/2 w, 10%	01121	EB 4721
A7R18	41-150K	150K, fixed, comp., 1/2 w, 10%	01121	EB 1541
A7R19		Same as A7R16		
A7R20 and A7R21	41-1M	1M, fixed, comp., 1/2 w, 10%	01121	EB 1051
A7R22	41-27K	27K, fixed, comp., 1/2 w, 10%	01121	EB 2731
A7TP1 and		**TEST POINTS**		
A7TP1 and A7TP2	133-85	Test Jack, Red	78947	119437B

TRANSFER OSCILLATOR PC BOARD A9 (Assy. 950635)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		CAPACITORS		
A9C1	12-3	.01 mf, fixed, ceramic, 500 v	71590	DD-1032
A9C2	12-2	.001 mf, fixed, ceramic, 500 v (S/N 137 and above)	71982	851-X5R-102K
	12-27	270 pf, fixed, ceramic, 1000 v (S/N 136 and below)	71590	DD-271
A9C3*	11-2	24 pf, fixed, mica, 5% (S/N 137 and above)	72136	CM15E240J
	11-6	15 to 27 pf, factory select, Nominal value (S/N 136 & below)	00853	DR-5-C-150-0
A9C4	12-27	270 pf, variable, 500 v	71590	DD-271
A9C5	23-5	1-12 pf, variable, 750 v	73889	58G
A9C6	12-2	.001 mf, fixed, ceramic, 500 v (S/N 136 and below)	71982	851-X5R-102K
	12-9	.05 mf, fixed, ceramic, 75 v,20% (S/N 137 and above)	71590	DDA-503
A9C7	12-12	30 pf, fixed, ceramic, 6Kv	71590	DD60-300
A9C8*	11-27	10 pf, fixed, mica, 2%, Factory selected, Nominal value	00853	D15-5-E-100-J
A9C9		Same as A9C7		
A9C10	11-18	12 pf, fixed, mica, 2%	00853	D15-5-E-120-J-0

TRANSFER OSCILLATOR PC BOARD A9 (con'd)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		CAPACITORS (Con'd)		
A9C11	11-20	5 pf, fixed, mica, 5%	00853	D15-5-E-050-J-0
A9C12	12-28	.001 mf, fixed, ceramic, 6Kv	71590	DD60-102
A9C13	11-6	15 pf, fixed, mica, 5%	00853	DR5C150-0
A9C14		Same as A9C1 (S/N 137 and above) Not used (S/N 136 and below)		
A9C15		Same as A9C2 (S/N 137 and above) Not used (S/N 136 and below)		
A9C16		Not used		
A9C17	12-36	1000 pf, feed thru, 500 v	00656	BSF 1CC
A9C18 and A9C19	12-45	10 pf, feed thru, 500 v	01121	FB2B-100w
A9C20 thru A9C22 **	11-18	12 pf, fixed, mica (S/N 112 & above)	00853	D155E120-0
		DIODES		
A9CR1 and A9CR2	81-132	1N914 (S/N 137 and above)	09022	1N914
	81-27	1N625 (S/N 136 and below)	73293	1N625
A9CR3 and A9CR4	81-132	1N914 (S/N 137 and above)	09022	1N914
	81-27	1N625 (S/N 136 and below)	73293	1N625
A9CR5	81-41	1N459	04713	1N459
		INDUCTORS		
A9L1 and A9L2		Not used (S/N 137 and above)		
	92-5	33 microhy R.F. (S/N 136 and below)	71895	1025-56
A9C3	92-26	.33 microhy R.F.	71895	1025-08
A9L4	92-24	2.2 microhy R.F.	71895	1537-20
A9L5	92-20	4.7 microhy R.F.	71895	1025-36
A9L6 and A9L7	92-36	18 microhy R.F.	03782	B950779
A9L8	92-18	1 microhy, R.F. (S/N 137 and above) Same as A9L6 (S/N 136 & below)	71895	1025-20
A9L9	92-18	1 microhy, R.F. (S/N 137 & above)	71895	1025-20
	92-7	10 µ hy (S/N 136 and below)	71895	1025-44
A9L10	92-18	1 microhy R.F. (S/N 137 and above) Not used (S/N 136 & below)	71895	1025-20
		TRANSISTORS		
A9Q1	81-105	2N708	07029	2N708
A9Q2 and A9Q3	81-188	2N3643 (S/N 137 and above) 2N3563/2N706 (S/N 136 and below)	07263	2N3643
A9Q4	81-131	Same as A9Q2 (S/N 137 and above) 2N708 (S/N 136 and below)	07263	2N3563
		RESISTORS		
A9R1	37-12K	12K, fixed, comp., 1/4 w, 10% (S/N 137 and above)	01121	CB 1231
	41-27K	27K, fixed, comp., 1/2 w, 10% (S/N 136 and below)	01121	EB 2731
A9R2	41-100 Ω	100 Ω, fixed, comp., 1/2 w, 10%	01121	EB 1011
A9R3	41-1K	1K, fixed, comp., 1/2 w, 10% (S/N 137 and above)	01121	EB 1021
	41-5.6K*	5K, factory select, nominal value (S/N 136 and below)	01121	EB 5621
A9R4	41-1K	1K, fixed, comp., 1/2 w, 10%	01121	EB 1021
A9R5	41-82 Ω	82 Ω, fixed, comp., 1/2 w, 10%	01121	EB 8201
A9R6	41-47K	47K, fixed, comp., 1/2 w, 10%	01121	EB 4731
A9R7	37-5.6K	5.6K, fixed, comp., 1/2 w, 10% (S/N 137 and above) Not used (S/N 136 and below)	01121	CB 5621
A9R8		Same as A9R6 (S/N 137 and above) Not used (S/N 136 and below)		
A9R9	37-390 Ω	390 Ω, fixed, comp., 1/4 w, 10% (S/N 137 and above) Not used (S/N 136 and below)	01121	CB 3911
		TRANSFORMERS		
A9T1	B950673	Transformer	03782	B950673
		TEST POINTS		
A9TP1	133-84	Jack Test Point	74868	26-159

* Factory Select

** Not used below indicated S/N.

SERIES REGULATOR PC BOARD A10 (Assy. 951083)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		CAPACITORS		
A10C1 thru A10C14		Not used		
A10C15	12-28	0.001 µf, 20%, fixed, ceramic, 6Kv	71590	DD60-102
A10C16 thru A10C19		Not used		
A10C20	12-9	0.05 µf, fixed, ceramic, 75 v	71590	DDA-503
A10C21 thru A10C24		Not used		
A10C25	12-3	0.01 µf, fixed, ceramic, 20%, 500 v	71590	DD-1032
		DIODES		
A10CR1 thru A10CR18		Not used		
A10CR19	81-41	1N459	04713	1N459
A10CR20 thru A10CR24		Not used		
A10CR25	81-138	Zener, 1N4757	04713	1N4757
		TRANSISTORS		
A10Q1 thru A10Q5		Not used		
A10Q6	81-115	2N3565	07263	2N3565
A10Q7	81-137	2N3568	07263	2N3568
		RESISTORS		
A10R1 thru A10R11		Not used		
A10R12	41-1K	1K, fixed, comp., 1/2 w, 10%	01121	EB 1021
A10R13 and A10R14	41-100 Ω	100 Ω, fixed, comp., 1/2 w, 10%	01121	EB 1011
A10R15		Same as A10R12		
A10R16 and A10R17		Same as A10R13		
A10R18		Same as A10R12		
A10R19 and A10R20		Same as A10R13		
A10R21	42-15K	15K, fixed, comp., 1 w, 10%	01121	GB 1531
A10R22	42-10K	10K, fixed, comp., 1 w, 10%	01121	GB 1031
A10R23	43-68K	68K, fixed, comp., 2 w, 10%	01121	HB 6831
A10R24	41-22K	22K, fixed, comp., 1/2 w, 10%	01121	EB 2231
A10R25	63-17	10K, fixed, WW, 20 w, 5%	35434	C20-10K-T5
A10R26		Not used		
A10R27		Same as A10R12		
A10R28 thru A10R51		Not used		
A10R52		Same as A10R13		
A10R53		Same as A10R12		
A10R54	56-178K	178K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-178K
A10R55	41-2.7K	2.7K, fixed, comp., 1/2 w, 10%	01121	EB 2721
A10R56	51-820 Ω	820 Ω, fixed, MF, 1/2 w, 5%	73445	E-009-AB/B-820 Ω
A10R57	41-12K	12K, fixed, comp., 1/2 w, 10%	01121	EB 1231
A10R58	41-8.2M	8.2M, fixed, comp., 1/2 w, 10%	01121	EB 8251
A10R59	41-100K	100K, fixed, comp., 1/2 w, 10%	01121	EB 1041
A10R60 thru A10R75		Not used		
A10R76	41-330 Ω	330 Ω, fixed, comp., 1/2 w, 10%	01121	EB 3311
A10R77 thru A10R81		Not used		
A10R82	42-470K	470K, fixed, comp., 1 w, 10%	01121	GB 4741
A10R83		Same as A10R12		
		TUBES		
A10V1	111-8068	Electron, 8068	33173	8068
A10V2	111-6CW5	Electron, 6CW5	73445	6CW5
		TUBE SOCKETS		
A10XV1	136-20	Octal	71785	8EM
A10XV2	136-19	9 pin, minature	95354	S161-125-PB
A10XV3 thru A10XV5		Same as XV1		

GRID-LEVELED LEVELER/AMPLIFIER PC BOARD A11 (Assy. 950621)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		CAPACITORS		
A11C1 and A11C2	12-34	0.1 µf, fixed, ceramic, 100 v	91418	BT 010
A11C3*	12-3	0.001 µf, factory selected, nominal value, 600 v	71982	851-X5R-102K
		DIODES		
A11CR1 and A11CR2	81-27	1N625	73293	1N625
		TRANSISTORS		
A11Q1	81-113	2N4956/NS7301	07263	2N4956
A11Q2	81-114	2N3638A	07263	2N3638A
A11Q3	81-73	2N706	07263	2N706
A11Q4	81-72	2N699	96214	2N699
		RESISTORS		
A11R1	71-102	100 Ω, variable	71450	XHT201-100 Ω
A11R2	41-100 Ω	100 Ω, fixed, comp., 1/2 w, 10%	01121	EB 1011
A11R3	41-6.8K	6.8K, fixed, comp., 1/2 w, 10%	01121	EB 6821
A11R4	41-1.2K	1.2K, fixed, comp., 1/2 w, 10%	01121	EB 1221
A11R5	41-560 Ω	560 Ω, fixed, comp., 1/2 w, 10%	01121	EB 5611
A11R6*	41-100 Ω	100 Ω, factory selected, nominal value	01121	EB 1011
A11R7	41-1K	1K, fixed, comp., 1/2 w, 10%	01121	EB 1021
A11R8	41-10K	10K, fixed, comp., 1/2 w, 10%	01121	EB 1031
A11R9	41-470 Ω	470 Ω, fixed, comp., 1/2 w, 10%	01121	EB 4711
A11R10	41-2.2K	2.2K, fixed, comp., 1/2 w, 10%	01121	EB 2221
A11R11	41-3.3K	3.3K, fixed, comp., 1/2 w, 10%	01121	EB 3321
A11R12		Same as A11R8		
A11R13	41-56K	56K, fixed, comp., 1/2 w, 10%	01121	EB 5631
A11R14 and A11R15	41-1M	1M, fixed, comp., 1/2 w, 10%	01121	EB 1051

GRID-LEVELED CIRCUIT INTERCONNECTION MODULE $A11_1$ (Assy. 901505-1)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		LAMPS		
$A11_1DS1$	126-11	Indicator	72765	116-303
		CONNECTORS		
$A11_1J1$	133-62	KZ10S, Plug-in socket	81312	KZ 10S
$A11_1P26$	133-32	Plug, M9P-LSH	81312	M9P-LSH
		RESISTORS		
$A11_1R1$	41-100K	100K, fixed, comp., 1/2 w, 10%	01121	EB 1041
$A11_1R2$	41-330 Ω	330 Ω, fixed, comp., 1/2 w, 10%	01121	EB 3311
$A11_1R3$		Potentiometer, 1K, (Part of $A11_1S1$)	01121	
$A11_1R4$	71-101	250 Ω, variable, comp., 1/2 w, 10%	71450	BJ 49642
$A11_1R5$*	41-470 Ω	470 Ω, fixed, comp., 1/2 w, 10% (Factory selected. Not normally used)	01121	EB 4711
		SWITCHES		
$A11_1S1$	102-134	Rotary (with 1K pot., $A11_1R3$)	71450	211ND-45NS

* Factory Select

PIN DIODE LEVELER/AMPLIFIER PC BOARD A11 (Assy. 951088)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		CAPACITORS		
A11C1 and A11C2	14-37	0.1 µf, fixed, film, 10%, 80 v	56289	192P1049R8
A11C3	14-42	0.0082 µf, fixed, porcelain, 10% 80 v	56289	192P8229R8
A11C4	11-36	150 pf, fixed, dipped mica, 10% 100 v	00853	D15-5-E-470-J
A11C5	11-25	47 pf, fixed, dipped mica, 5% 100 v	00853	D15-5-E-470-J
A11C6	11-37	200 pf, fixed, dipped mica, 10%, 100 v	72136	DM-10-201-K
A11C7 and A11C8	11-28	82 pf, fixed, dipped mica, 2%	00853	D15-3-E-82-G-O
A11C9		Same as A11C1		
A11C10	13-68	3.3 µf, fixed, 10%, 15 v	22229	K3R3C15K
A11C11	12-2	0.001 µf, fixed, 100 v	71982	851-X5R-102K
		DIODES		
A11CR1 thru A11CR3	81-132	1N914	07263	1N914
		TRANSISTORS		
A11Q1	81-194	Sprague TD100	56289	TD 100
A11Q2	81-115	2N3565	07263	2N3565
A11Q3 and A11Q4	81-140	2N5087/2N4250	04713	2N5087/2N4250
A11Q5		Same as A11Q2		
A11Q6		Same as A11Q1		
A11Q7 thru A11Q11	81-189	2N4917	07263	2N4917
A11Q12 and A11Q13	81-169	2N3569	07263	2N3569
A11Q14	81-72	NPN, 2N699	96214	2N699
		RESISTORS		
A11R1	59-26.7K	26.7K, fixed, MF, 1/4 w, 1%	19701	MF-5C-TO-26.7K
A11R2	59-26.1K	26.1K, fixed, MF, 1/4 w, 1%	19701	MF-5C-TO-26.1K
A11R3 and A11R4	59-1K	1K, fixed, MF, 1/4 w, 1%	19701	MF-5C-TO-1K
A11R5	71-136	250 Ω, variable, comp., 0.2 w,30%	71450	U201R251B
A11R6 and A11R7	34-10K	10K, fixed, comp., 1/4 w, 5%	01121	CS 1035
A11R8	34-4.7K	4.7K, fixed, comp., 1/4 w, 5%	01121	CS 4725
A11R9		Same as A11R6		
A11R10 and A11R11	34-560 Ω	560 Ω, fixed, comp., 1/4 w, 5%	01121	CS 5615
A11R12 and A11R13		Same as A11R6		
A11R14	34-5.6K	5.6K, fixed, comp., 1/4 w, 5%	01121	CS 5625
A11R15	34-4.3K	4.3K, fixed, comp., 1/4 w, 5%	01121	CS 4325
A11R16	34-1.8K	1.8K, fixed, comp., 1/4 w, 5%	01121	CS 1825
A11R17	71-135	1.5K, variable, comp., 0.2 w, 30%	71450	U201R152B
A11R18		Same as A11R14		
A11R19 and A11R20	34-390 Ω	390 Ω, fixed, comp., 1/4 w, 5%	01121	CS 3915
A11R21		Same as A11R8		
A11R22	34-8.2K	8.2K, fixed, comp., 1/4 w, 5%	01121	CS 8225
A11R23	34-1K	1K, fixed, comp., 1/4 w, 5%	01121	CS 1025
A11R24		Same as A11R6		
A11R25	34-15K	15K, fixed, comp., 1/4 w, 5%	01121	CS 1535
A11R26	34-330 Ω	330 Ω, fixed, comp., 1/4 w, 5%	01121	CS 3315
A11R27		Same as A11R26		
A11R28 and A11R29	34-820 Ω	820 Ω, fixed, comp., 1/4 w, 5%	01121	CS 8215
A11R30		Same as A11R8		
A11R31		Same as A11R6		
A11R32	34-2.2K	2.2K, fixed, comp., 1/4 w, 5%	01121	CS 2225
A11R33	34-220 Ω	220 Ω, fixed, comp., 1/4 w, 5%	01121	CS 2215
A11R34		Same as A11R26		
A11R35		Same as A11R23		
A11R36		Same as A11R28		
A11R37 and A11R38		Same as A11R23		
A11R39	34-1.5K	1.5K, fixed, comp., 1/4 w, 5%	01121	CS 1525
A11R40 and A11R41		Same as A11R25		
A11R42	71-134	500 Ω, variable, comp., 2 w,30%	71450	U201R501B
A11R43	34-33K	33K, fixed, comp., 1/4 w, 5%	01121	CS 3335
A11R44	34-12K	12K, fixed, comp., 1/4 w, 5%	01121	CS 1235
A11R45 and A11R46		Same as A11R23		
A11R47	59-100K	100K, fixed, MF, 1/4 w, 1%	19701	MF-5C-TO-100K
A11R48	59-133K	133K, fixed, MF, 1/4 w, 1%	19701	MF-5C-TO-133K

PIN DIODE LEVELER POWER SUPPLY PC BOARD A11PS (Assy. 951087)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		CAPACITORS		
A11PSC1†	13-72	1000 µf, fixed, elect., 25 v	56289	TL 1218
A11PSC2†	12-52	0.47 µf, fixed, ceramic, 25 v	71982	5865-000-Y5UP-474Z
A11PSC3†	13-49	50 µf, fixed, elect., 25 v	56289	TE 1209
		DIODES		
A11PSCR1	81-178	Rectifier Bridge Assy., Motorola MSA-920A-2	04713	MDA-920A-2
A11PSCR2	81-123	Zener, 1N749A	04713	1N749A
		TRANSISTORS		
A11PSQ1	81-133	40372	07029	40372
A11PSQ2	81-114	2N3638A	07263	2N3638A
A11PSQ3	81-169	2N3569	07263	2N3569
		RESISTORS		
A11PSR1	51-10K	10K, fixed, dep. carb., 1/2w,5%	73445	E-009-AB/B-10K
A11PSR2	51-1.5K	1.5K, fixed, dep. carb., 1/2w,5%	73445	E-009-AB/B-1.5K
A11PSR3	51-1.2K	1.2K, fixed, dep. carb., 1/2w,5%	73445	E-009-AB/B-1.2K
A11PSR4	51-390 Ω	390 Ω, fixed, dep. carb., 1/2 w, 5%	73445	E-009-AB/B-390 Ω
A11PSR5	51-680 Ω	680 Ω, fixed, dep., carb., 1/2 w, 5%	73445	E-009-AB/B-680 Ω
A11PSR6	71-95	2K, variable, 1w, 10%, 20 turn	21030	79PR2K
		TRANSFORMERS		
A11PST1	A951814	A951814	03782	A951814

† On units where C1 is mounted on the main chassis, A11PSC2 was labeled A11PSC1 and A11PSC3 was labeled A11PSC2.

PIN DIODE LEVELER CONTROL CIRCUIT INTERCONNECTION MODULE A11$_2$ (Assy. 901504)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		LAMPS		
A11$_2$DS1	126-11	Indicator, neon	72765	116-303
		CONNECTORS		
A11$_2$J1		Not used		
A11$_2$J2	133-63	KZ 22S, P.C. Plug-in, 22 pin	81312	KZ 22S
		RESISTORS		
A11$_2$R1	51-330 Ω	330 Ω, fixed, dep. carb., 1/2 w, 5%	73445	E-009-AB/B-330 Ω
A11$_2$R2	51-390 Ω	390 Ω, fixed, dep. carb., 1/2 w, 5%	73445	E-009-AB/B-390 Ω
A11$_2$R3	51-15K	15K, fixed, dep. carb., 1/2 w,5%	73445	E-009-AB/B-15K
A11$_2$R4	51-56K	56K, fixed, dep. carb., 1/2 w,5%	73445	E-009-AB/B-56K
A11$_2$R5	51-1.5K	1.5K, fixed, dep. carb., 1/2 w, 5%	73445	E-009-AB/B-1.5K
A11$_2$R6 (Part of A11$_2$S2)	(102-134)	1K, variable (part of A11$_2$S2)		
		SWITCHES		
A11$_2$S1		Not used		
A11$_2$S2	102-134	1K, rotary, pot (R9)	71450	211ND-45NS

ELEVATED SUPPLY PC BOARD A12 (Assy. 901488)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		CAPACITORS		
A12C1	12-28	0.001 mf, fixed, ceramic, 6Kv, 20%	71590	DD60-102
A12C2	11-2	24 pf, fixed, ceramic, 600 v	72136	CM15-E240-J
A12C3 and A12C4	12-3	0.01µf, fixed, ceramic, 600 v	71590	DD-1032
		DIODES		
A12CR1	81-20	1N4385 (S/N 87 & above)	76433	1N4385
	81-41	1N459 (S/N 86 & below)	93332	1N459
A12CR2	81-41	1N459	93332	1N459
A12CR3		Same as A12CR1		
A12CR4		Same as A12CR2		
A12CR5 and A12CR6	81-156	Zener, 15 v, 1 w, MZ1000-17/ 1N4744	04713	MZ1000/17
		INDUCTORS		
A12L1	92-22	RF, 33 µh	71895	1537-52
		TRANSISTORS		
A12Q1	81-72	2N699	96214	2N699
		RESISTORS		
A12R1	51-150K	150K, fixed, carb., film, 1/2w, 5%	73445	E-009-AB/B-150K
A12R2*		Factory Installed (see Addendum A)		
A12R3		Not used		
A12R4	35-1.1K	1.1K, fixed, met. film, 1/2 w, 5%	16299	C-42-1.1K-2W
A12R5	50-820 Ω	820 Ω, fixed, Tin Oxide, 2w, 2%	10299	C-42S-820 Ω -2W
A12R6	51-7.5K	7.5K, fixed, carb., film, 1/2w, 5%	73445	E-009-AB/B-7.5K
A12R7	45-12K	12K, fixed, comp., 1 w, 5%	01121	GB 1235
A12R8	51-10 Ω	10 Ω, fixed, comp., 1/2 w, 5%	73445	E-009-AB/B-10 Ω
A12R9	71-103	50K, variable	03782	71-103
A12R10	56-237K	237K, fixed, met. film, 1/2 w, 1%	19701	MF-7C-TO-237K
A12R11	51-8.2K	8.2K, fixed, comp., 1/2 w, 5%	73445	E-009-AB/B-8.2K
A12R12*		(Not used except as a substitute for A12R14 See Addendum A)		
A12R13	56-10 Ω	10 Ω, fixed, met. film, 1/2 w, 1%	19701	MF-7C-TO-10 Ω
A12R14*		Factory selected (see Addendum A)		
A12R15*		Factory selected (see Addendum A)		
A12R16		Not used		
A12R17	51-180K	180K, fixed, carb. film, 1/2w, 5%	73445	E-009-AB/B-180K
A12R18	51-27K	27K, fixed, carb. film, 1/2 w, 5%	73445	E-009-AB/B-27K

*Factory Select

DIODE SHAPER PC BOARD A13***

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		CAPACITORS		
A13C1 thru A13C3	12-34	0.1 µf, fixed, ceramic, 100 v	91418	BT 010
A13C4	12-22	100 pf, fixed, ceramic, 500 v	71982	831-X5R-101K
A13C5 and A13C6		Same as A13C1		
		DIODES		
A13CR1 thru A13CR14	81-41	1N459	07263	1N459
		TRANSISTORS		
A13Q1 and A13Q2	81-115	2N3565	07263	2N3565
		RESISTORS		
A13R1 thru A13R11		See Table on Schematic C900713		
A13R12 thru A13R14		Not used		
A13R15	56-750 Ω	750 Ω, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-750 Ω
A13R16	56-121 Ω	121 Ω, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-121 Ω
A13R17 thru A13R23	56-100 Ω	100 Ω, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-100 Ω
A13R24	56-80.6 Ω	80.6 Ω, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-80.6 Ω
A13R25	56-1K	1K, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-1K
A13R26	71-90	200 Ω, variable, WW, 20 turns, 1 w	21030	79PR200
A13R27	41-1.8K	1.8K, fixed, comp., 1/2 w, 10%	01121	EB 1821
A13R28	71-94	5K, variable, WW, 20 turns	21030	79PR5K
A13R29	41-27K	27K, fixed, comp., 1/2 w, 10%	01121	EB 2731
A13R30	41-10K	10K, fixed, comp., 1/2 w, 10%	01121	EB 1031
A13R31	41-150K	150K, fixed, comp., 1/2 w, 10%	01121	EB 1541

FILAMENT PROTECTION PC BOARD A14 (Assy. 951137)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		CAPACITORS		
A14C1 thru A14C21		Not used		
A14C22	12-34	0.1 µf, ceramic, 100 v	91418	BT 010
		LAMPS		
A14DSR1	B951044	Photo Cell Assembly	03782	B951044
		RELAYS		
A14K1	106-29	RS5D-6VDC	77342	RS5D-6VDC
A14K2 and A14K3		Not used		
A14K4	106-24	RS5D-10K	77342	RS5D-10K
		RECTIFIERS		
A14Q1 thru A14Q8		Not used		
A14Q9	81-147	Silicon Control, CG-6/2N1671B	03508	C6G/1671B
		RESISTORS		
A14R1 thru A14R59		Not used		
A14R60	41-1K	1K, fixed, comp., 1/2 w, 10%	01121	EB 1021
A14R61	41-6.8K	6.8K, fixed, comp., 1/2 w, 10%	01121	EB 6821
A14R62	56-38.3Ω	38.3 Ω, fixed, MF, 1/2 w, 1%	19701	MF-7C-TO-38.3Ω
A14R63 thru A14R65		Not used		
A14R66	41-470 Ω	470 Ω, fixed, comp., 1/2 w, 10%	01121	EB 4711

RECTIFIER ASSEMBLY PC BOARD A15 (Assy. 951061)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		CAPACITORS		
A15C1	13-62	100 µf, fixed, elect., 50 v, axial	56289	TVA 1310
A15C2 ***	12-29	.05 µ f, fixed, ceramic, 600 v	71590	DD 503
A15C3 ***	12-31	.022 µ f, fixed, ceramic, 300 v	56289	5GA-S25
		DIODES		
A15CR1 thru A15CR4	81-143	Rectifier circuit, single phase, full wave bridge, MDA 920A-6 (BF)	04713	MDA-920A-6(BF)
A15CR5	81-144	Rectifier circuit, single phase, center tap common anode, MDA 950A-6(CP)	04713	MDA-950A-6(CP)
A15CR6	81-135	EH 400 (S/N 56 & above)	85701	EH 400
(A & B)	81-160	Voltage Doubler DI-5424 (S/N 36 thru 55)	12060	DI-5424
	81-69	Silicon, DI-1154 (S/N 35 & below)	12060	DI-1154
A15CR7	81-159	Bridge Rectifier, DI-BR905A (S/N 36 and up)	12060	BR 905A
	81-82	Silicon MR-322 (S/N 1 thru 35)	04713	MR 322
A15CR8		Not used in S/N 36 & up		
	81-82	Silicon, MR-322 (S/N 1 thru 35)	04713	MR 322
A15CR9		Not used in S/N 36 & up Same as A15CR5 in S/N 1 thru 35		

*** S/N 56 and above; optional in S/N 55 and below.

BLEEDER PC BOARD A26 (Assy. 951249)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		CAPACITORS		
A26C1 and A26C2	12-33	0.01 µf, fixed, ceramic, 20%, 3Kv	56289	30GA-S10
A26C3		Not used		
A26C4 and A26C5	15-21	2 µf, fixed, oil, phenolic case, 20%, 2Kv	00686	KM7-20-2MS1
		RESISTORS		
A26R1 thru A26R8	42-470K	470K, fixed, comp., 10%, 1w	01121	GB 4741

***/see Table on Schematic C900713 for applicable assembly number

TABLE OF MICROWAVE COMPONENTS

Frequency GHz.	6400 Model No.	Tube Type	Alfred Tube No.	Sampler	Sampler Attenuator	Low Pass Filter
1 to 2	6410 thru 6415	Stewart	112-029	951099	1151 951253[xx]	256-6[y]
1.4 to 2.5	6410-1 thru 6415-1	Stewart	112-034	950781	1151-1 951254[xx]	
1.7 to 4.2	6420-1 thru 6423-1	Stewart	112-033	950908		256-9[y]
2 to 4	6420 thru 6425	Stewart W-J Varian	112-031 112-095 112-015	951100	1152 951255[xx]	256-2[y] xxxx
3.5 to 6.75	6430-1 thru 6435-1	Stewart Varian	112-035 112-016	950783	1153-1 951257[xx]	256-4[y] xxxx
3.7 to 8.3	6430-2 thru 6433-2	Stewart Varian	112-028 112-017	950896		256-8[y] xxxx
4 to 8	6430 thru 6435	Stewart Varian	112-027 112-006	950784	1153 951256[xx]	256-1[y]
7 to 11	6440 thru 6443	Varian Watkins-Johnson	112-012 112-039	951101		256-5[y]
7 to 12.4	6440-1 thru 6443-1	Varian Watkins-Johnson	112-012 112-039	951101		256-5[y]
8 to 12.4	6450 thru 6453	Varian Watkins-Johnson	112-013 112-038	950786		256-5[y]
10 to 15.5	6460	Varian	112-014		950866***	
12.4 to 18	6470 6471	Varian	112-009	950892	— 950815***	
18 to 26.5	6480	Varian	112-010		950868***	
26.5 to 40	6490	Varian	112-011		950867***	

[y] Used only on 64(*)1 and 64(*)3 units. *** Flap Attenuator
[xx] Model 64(*)4 and 64(*)5 only xxxx Self-contained in BWO

ANODE PROTECTION PC BOARD A19 (Assy. 951155)[ttt]

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		CAPACITORS		
A19C1	12-34	Fixed, ceramic, 0.1 µf, 100 v	91418	BT 010
		DIODES		
A19CR1	81-20	1N4385	76433	1N4385
		TRANSISTORS		
A19Q1	81-145	SCS 3N85	03508	SCS 3N85
A19Q2	81-182	SCR C106C1	03508	SCR C106C1
A19Q3	81-114	2N3638A	07263	2N3638A
		RESISTORS		
A19R1	43-470 Ω	Fixed, comp., 470 Ω, 2 w, 10%	01121	HB 4711
A19R2	71-98	Variable, 200 Ω, 2 w	71450	115-200 Ω
A19R3 and A19R4	41-10K	Fixed, comp., 10K, 1/2 w, 10%	01121	EB 1031
A19R5		Not used		
A19R6	71-111	Variable, 25K, 1/4 w	71450	XHT-201-25K
A19R7	41-470 Ω	Fixed, comp., 470 Ω, 1/2 w, 10%	01121	EB 4711
		ZENER DIODES		
A19VR1	81-183	MZ 500-11	04713	MZ 500-11

[ttt] Used with Varian BWO Tubes Only.

SECTION 7 — SCHEMATIC DIAGRAMS

Schematics are included in the following order:

Main Chassis	D900845	
Cathode Supply PC Board A1	C900770	
Low Voltage Supply PC Board A2	C900766	
Sweep PC Board A3	C900887	
Markers PC Board A4	C900733	
Modulator PC Board A5	C900714	
Auxiliary Supply PC Board A6	C900909	
Helix Overcurrent PC Board A7	C900843	
Transfer Oscillator PC Board A9	C900747	Rev. 0 (S/N 136 & below) Rev. S (S/N 137 & up)
Series Regulator/Retrace Discharge PC Board A10	C900906	
Leveler Schematics for Grid-leveled units (Models 64(*)0, 64(*)1, and 64(*)4)		
Grid-leveled Circuit Interconnection Module $A11_1$	C900872	
Grid-leveled Leveler Amplifier PC Board A11	C900730	
Leveler Schematics for PIN-leveled units (Models 64(*)2, 64(*)3, and 64(*)5)		
PIN Diode Leveler Power Supply PC Board $A11_{PS}$	B900930	
PIN Diode Leveler Circuit Interconnection Module $A11_2$	C907055	
PIN Diode Leveler Amplifier PC Board A11	D900933	
Elevated Supply PC Board A12	C900869	
Diode Shaper PC Board A13	C900713	
Filament Protection PC Board A14	C900910	
Rectifier Assembly PC Board A15	B900905	
Anode Protection PC Board A19	B900940	
Bleeder Assembly PC Board A26	C900955	

NOTES:

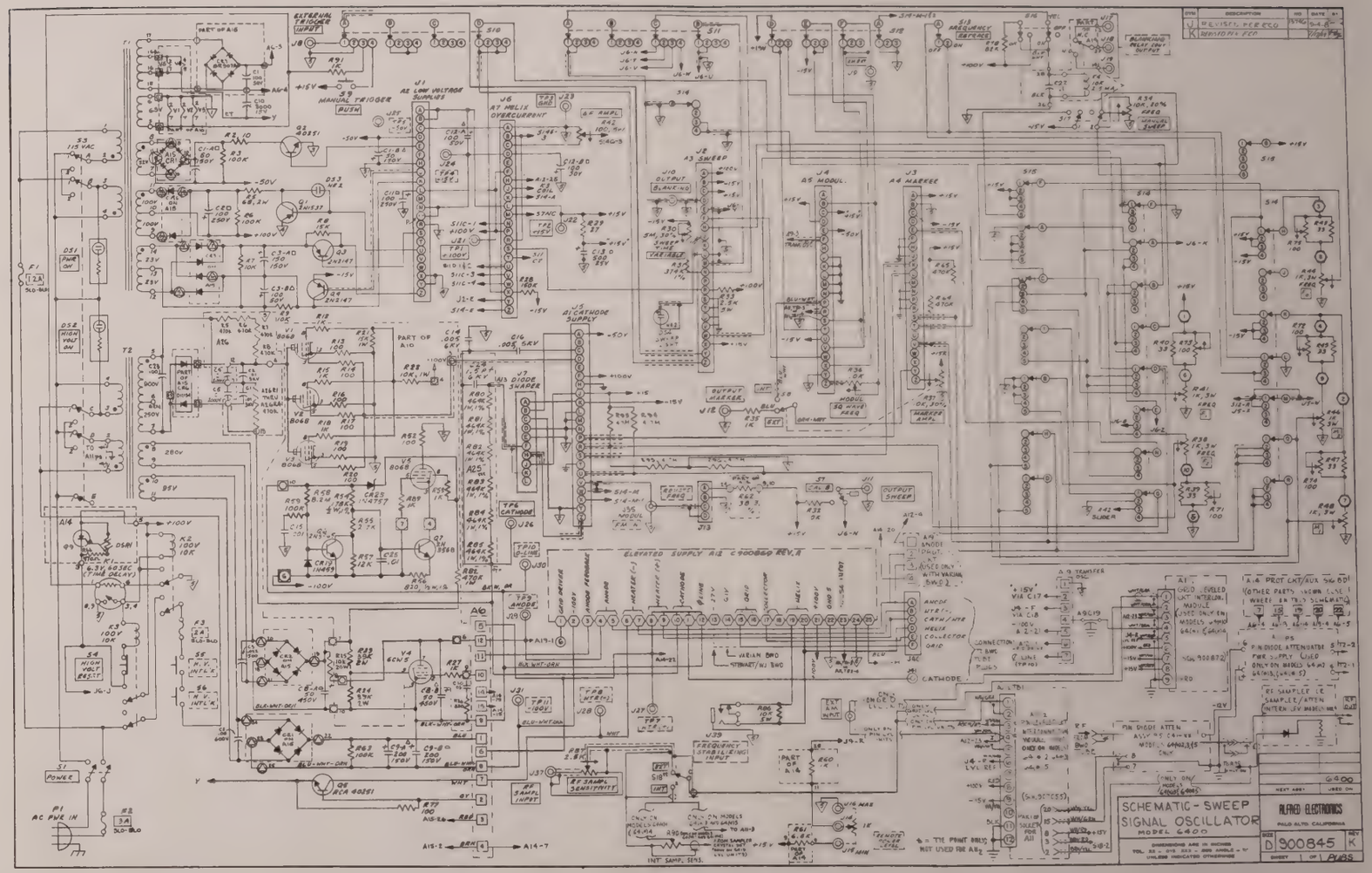
1. Unless otherwise specified:

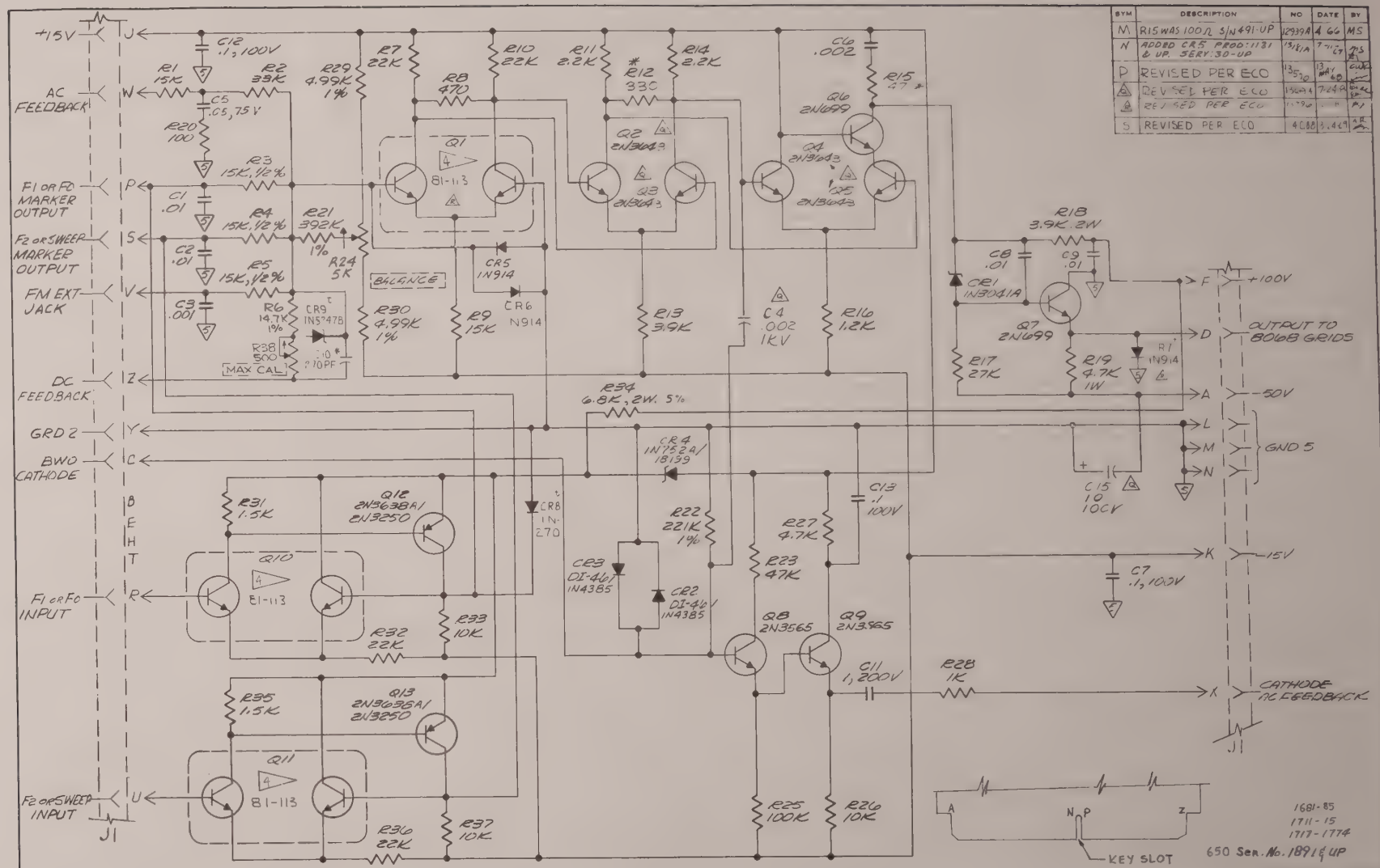
   All resistors in ohms, 1/2 W, 10%, All capacitors in microfarads, All rotary switches shown in CCW position, All relays shown in de-energized position, Arrows on potentiometers indicate CW position.

2. ⑴ thru ⑸ denotes ground returns.
3. ⬡ = terminals on A16-dial box and trimpot assembly.
4. ○ = terminals on A9 transfer oscillator assembly.
5. ▣ = terminals on A10TB1.
6. △ = terminals on A15.
7. Grid-leveled units are Models 64(*)0, 64(*)1, and 64(*)4; Pin-leveled units are Models 64(*)2, 64(*)3, and 64(*)5.
8. See page 7-0 for key to schematics vs. A-numbers.
9. tt = On Models 64(*)0 and 64(*)2, S18 is not used, and the switch is bypassed by wiring S18C directly to S18-1.
10. ttt = A25 is not silk screened.
11. Switch position numbers vs. panel markings:

SWITCH	SW. POS.	MODE OF OPERATION
S10	1	EXTERNAL
S10	2	FREE RUN
S10	3	LINE
S10	4	MANUAL
S11	1	10
S11	2	1.0
S11	3	0.1
S11	4	.01
S12	1	AM EXTERNAL
S12	2	AM OFF
S12	3	SQ. WAVE
S14	1	SINGLE
S14	2	OFF
S14	3	$F_0 \pm \Delta F$
S14	4	F_1 F_2
S15	1	F_1
S15	2	M_1
S15	3	F_0
S15	4	M_2
S15	5	F_1

REF DESIG NOT USED	LAST REF DESIG USED
R4 R79 J20 S2 R9 J32 R69 J33 R70 J34	R96, C24, J41, S19





SYM	DESCRIPTION	NO	DATE	BY
M	R15 WAS 100Ω S/N 491-UP	12939A	4-66	MS
N	ADDED CR5 PROD: 1131 & UP, SERV. 30-UP	13181A	7-11-67	MS
P	REVISED PER ECO	13530	13 MAY 68	GWD
Q	REVISED PER ECO	13694	7-24-68	RJ
R	REVISED PER ECO	13796	"	RJ
S	REVISED PER ECO	14080	3-14-69	RJ

1681-85
1711-15
1717-1774
650 Ser. No. 1891 & UP

NOTES:
1. UNLESS OTHERWISE SPECIFIED:
   1A. ALL RESISTORS IN OHMS, 1/2W, 10%
   1B. ALL RESISTORS 1/2% AND 1% ARE METAL FILM
   1C. ALL CAPACITORS IN MICROFARADS, 500V
2. ASSEMBLY NO. 950813
   P.C. BD. NO. 944069
3. PREFIX REFERENCE DESIGNATOR BY "A1" (IE: A1R1, A1Q13)

4 FOR FIELD SERVICE SUB NS7301 # 2N4956 MAY BE USED IN PLACE OF ALFRED 81-113

* INDICATES FACTORY SELECTED
† OPTIONAL ON 6400, # BELOW S/N 1891 ON 650
△ 2N3646 " " "

6/69

PART NO.	DESCRIPTION

LIST OF MATERIAL

MATERIAL
MATERIAL STOCK NO.
FINISH OR TREATMENT

DRAWN Ede Y. Stow 12-1-64
ENG Howard Hilbert 12-16-64
PROD Thos A. Hilbert 12-15-64
SCALE

SCHEMATIC CATHODE SUPPLY & FEEDBACK CKT "A1"

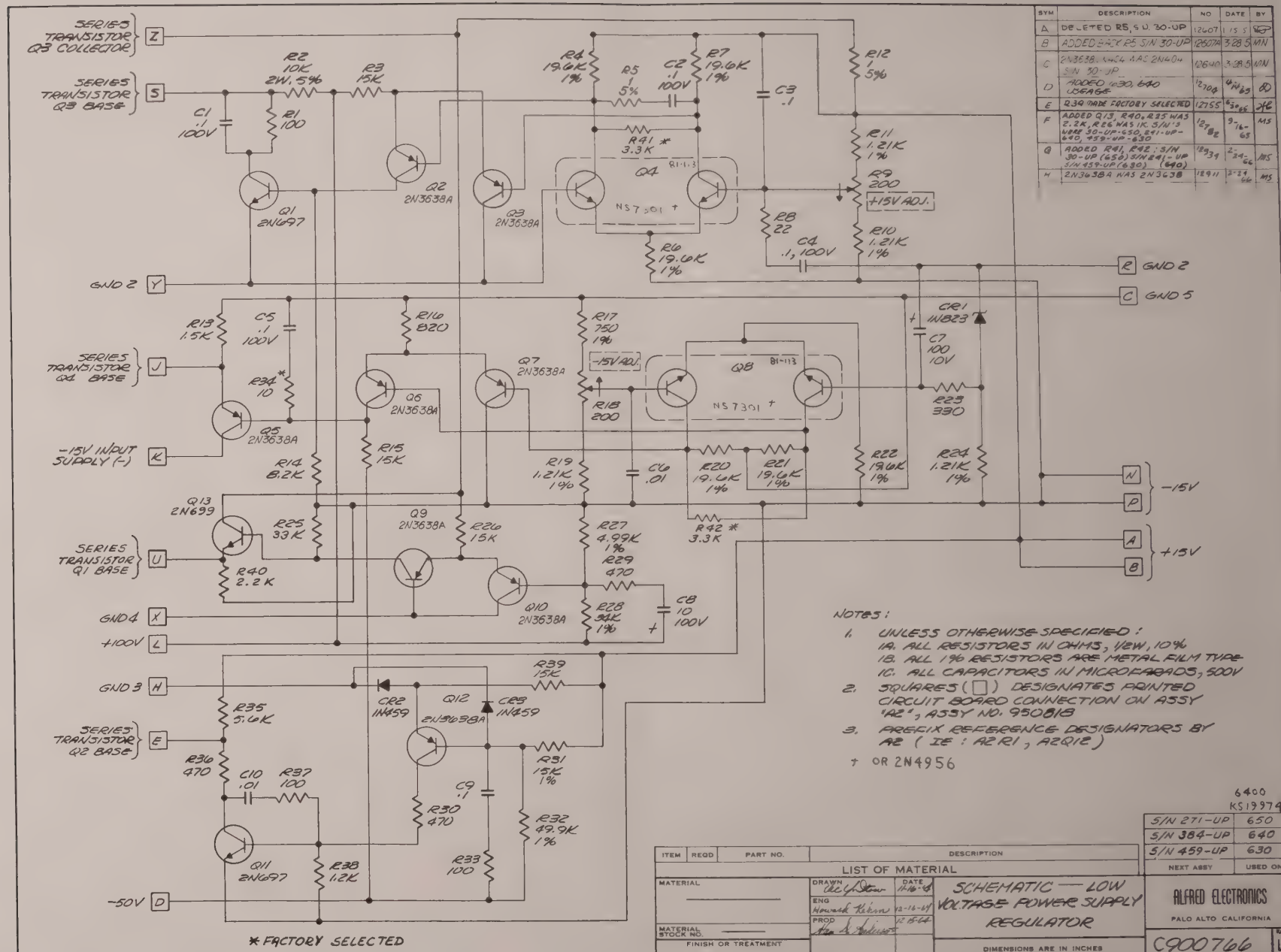
DIMENSIONS ARE IN INCHES
TOL .XX ± .015 .XXX ± .005 ANGLE ± ½°
UNLESS INDICATED OTHERWISE

650
6400
NEXT ASSY | USED ON

ALFRED ELECTRONICS
PALO ALTO, CALIFORNIA

C 900770 S

SHEET 1 OF 1



SYM	DESCRIPTION	NO	DATE	BY
A	DELETED R5, S/N 30-UP	12607	1-15-65	
B	ADDED BACK R5 S/N 30-UP	12607A	3-28-65	MN
C	2N3638 - MAC4 MAS 2N404 S/N 30-UP	12640	3-29-65	MN
D	ADDED Q30, 640 USEAGE	12709	4-23-65	RD
E	Q39 MADE FACTORY SELECTED	12755	6-30-65	JK
F	ADDED Q13, R40, R25 WAS 2.2K, REG WAS 1K. S/N 3 UPRF 30-UP-650, 641-UP-640, 459-UP-630	12788	9-16-65	MS
G	ADDED R41, R42; S/N 30-UP (650) S/N 641-UP S/N 459-UP (640)	12934	2-24-66	MS
H	2N3638A WAS 2N3638	12911	3-29-66	MS

Notes:

1. UNLESS OTHERWISE SPECIFIED:
   1A. ALL RESISTORS IN OHMS, 1/2W, 10%
   1B. ALL 1% RESISTORS ARE METAL FILM TYPE
   1C. ALL CAPACITORS IN MICROFARADS, 500V
2. SQUARES (□) DESIGNATES PRINTED CIRCUIT BOARD CONNECTION ON ASSY "A2", ASSY NO. 9508B
3. PREFIX REFERENCE DESIGNATORS BY A2 (IE: A2R1, A2Q12)

† OR 2N4956

6400
KS19974

S/N 271-UP	650
S/N 384-UP	640
S/N 459-UP	630
NEXT ASSY	USED ON

ITEM	REQD	PART NO.	DESCRIPTION

LIST OF MATERIAL

MATERIAL —
MATERIAL STOCK NO. —
FINISH OR TREATMENT —

DRAWN Alex Stew 11-16-64
ENG Howard Kline 12-16-64
PROD Ann L. Anderson 12-15-64
SCALE —

SCHEMATIC — LOW VOLTAGE POWER SUPPLY REGULATOR

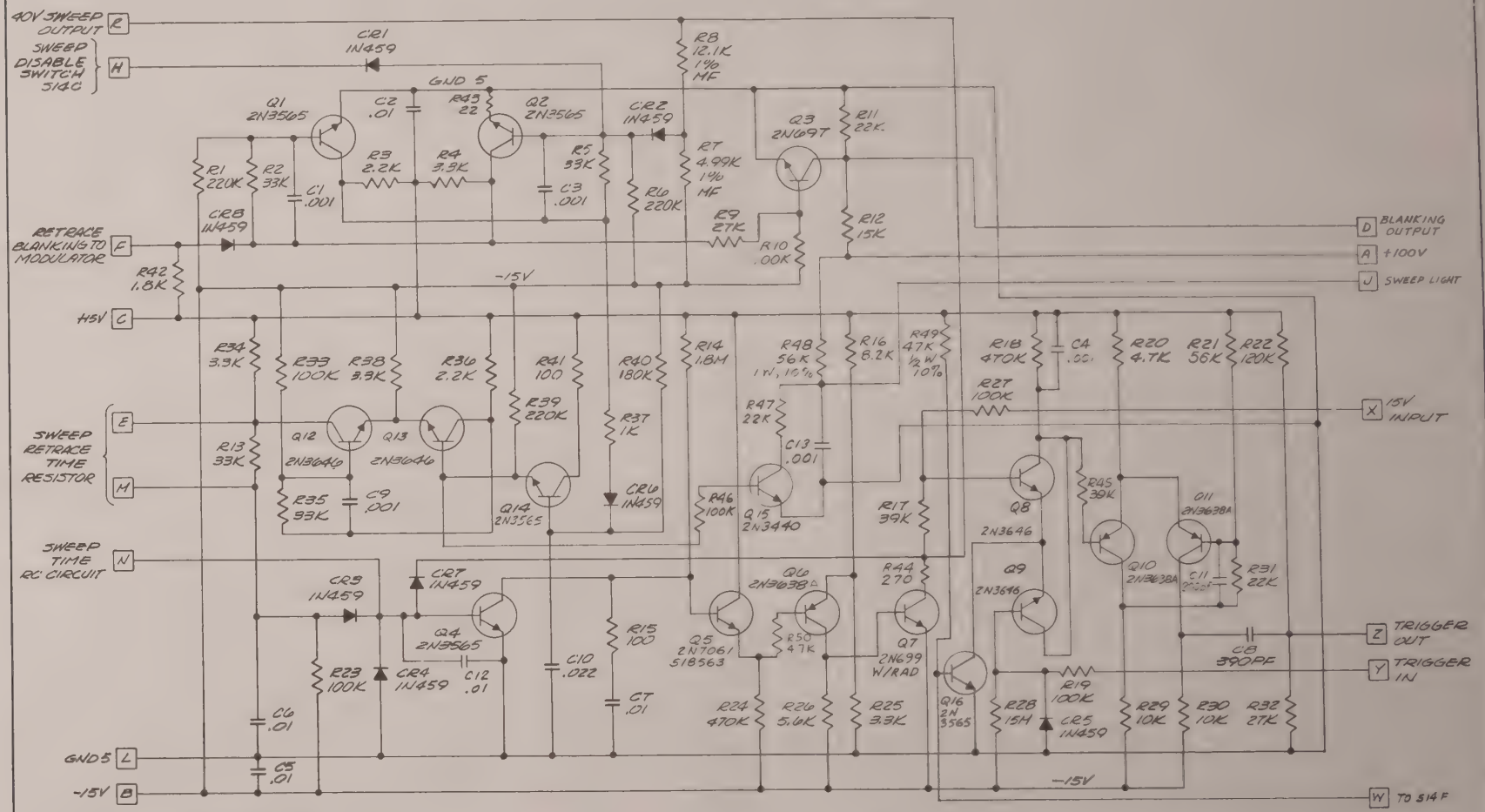
DIMENSIONS ARE IN INCHES
TOL: .XX ± .015, .XXX ± .005, ANGLE ± ½° UNLESS INDICATED OTHERWISE

ALFRED ELECTRONICS
PALO ALTO CALIFORNIA

C900766 REV L

SHEET 1 OF 1

SYM	DESCRIPTION	NO	DATE	BY
A	R50 ADDED	12176	5/22/67	[illegible]



NOTES:

1. UNLESS OTHERWISE SPECIFIED:
   - 1A. ALL RESISTOR IN OHMS, 1/2W, ±10%
   - 1B. ALL CAPACITOR IN MICROFARADS, 500V
2. SQUARES (□) DESIGNATES PRINTED CIRCUIT CONNECTION ON ASSY "A3", ASSEMBLY NO. 95045 (SN 11-UP)
3. PREFIX REFERENCE DESIGNATORS BY "A3" (I.E: A3R1, A3Q11)
4. REFER TO INSTRUCTION MANUAL FOR VALUE OF COMPONENT
5. P.C. ARTWORK NO. 94437.

* FACTORY SELECTED

ITEM	REQD	PART NO	DESCRIPTION

LIST OF MATERIAL

MATERIAL

MATERIAL STOCK NO

FINISH OR TREATMENT

	DRAWN	DATE
	ENG	
	PROD	

SCALE

SCHEMATIC SWEEP CIRCUIT "A3"

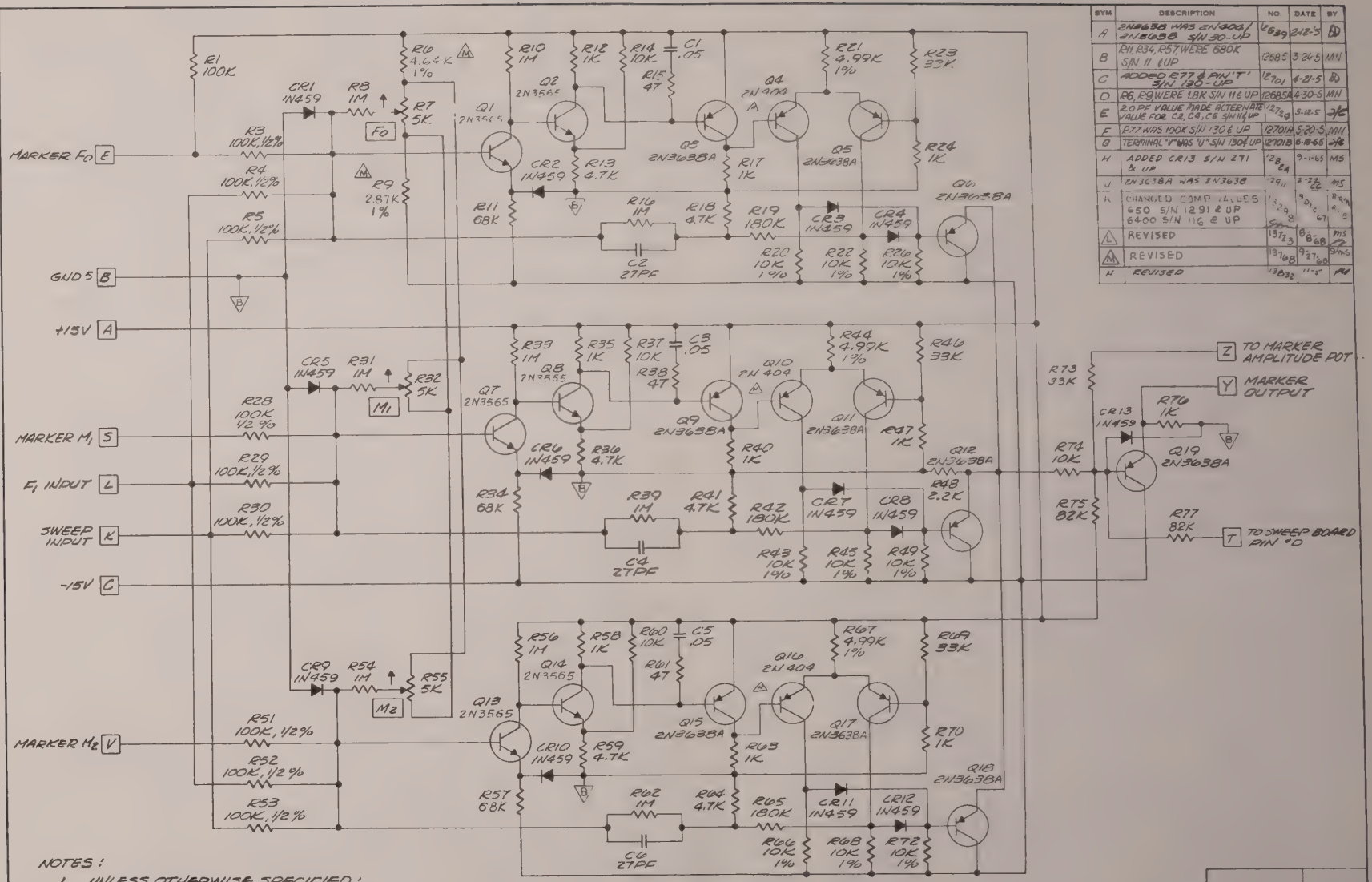
DIMENSIONS ARE IN INCHES
TOL: .XX ± .015, .XXX ± .005, ANGLE ± ½°
UNLESS INDICATED OTHERWISE

	650
3SR NO. 11-UP	6400
NEXT ASSY	USED ON

ALFRED ELECTRONICS
PALO ALTO CALIFORNIA

C 900887 REV A

SHEET 1 OF



SYM	DESCRIPTION	NO.	DATE	BY
A	2N6638 WAS 2N404/ 2N3638 S/N 130-UP	6639	2-18-5	BD
B	R11, R34, R57 WERE 680K S/N 11 &UP	12685	3-24-5	MN
C	ADDED R77 & PIN "T" S/N 130-UP	12701	4-21-5	BD
D	R6, R9 WERE 1.8K S/N 11& UP	12685A	4-30-5	MN
E	2.0 PF VALUE MADE ALTERNATE VALUE FOR C2, C4, C6 S/N 11& UP	12729	5-18-5	JHC
F	R77 WAS 100K S/N 130& UP	12701A	5-20-5	MN
G	TERMINAL "V" WAS "U" S/N 130& UP	12701B	6-8-65	JHC
H	ADDED CR13 S/N 271 & UP	12824	9-1-65	MS
J	2N3638A WAS 2N3638	12911	2-22-66	MS
K	CHANGED COMP VALUES 650 S/N 1291 & UP 6400 S/N 116 & UP	13208	9 DEC 67	RMM
L	REVISED	13743	8-8-68	MS
M	REVISED	13768	9-27-68	MS
N	REVISED	13832	11-5	AM

NOTES:
1. UNLESS OTHERWISE SPECIFIED:
   - 1A. ALL RESISTOR IN OHMS, 1/2W, 10%
   - 1B. ALL RESISTORS 1/2 % & 1% ARE METAL FILM TYPE
   - 1C. ALL CAPACITORS IN MICROFARADS, 500V
2. SQUARES (□) DESIGNATES PRINTED CIRCUIT CONNECTION ON ASSY "A4", ASSEMBLY NO. 950626 (SN 11-129), 950911 (SN 130-UP)
3. PREFIX REFERENCE DESIGNATORS BY A4 (IE: A4R1, A4Q1B)

ITEM	REQD	PART NO	DESCRIPTION

LIST OF MATERIAL

MATERIAL

MATERIAL STOCK NO

FINISH OR TREATMENT

	DRAWN	DATE
	V.C. Trow	2-28-64
ENG	H. Kehm	12-16-64
PROD		4-15-64

SCALE

DIMENSIONS ARE IN INCHES
TOL: .XX ± .015, .XXX ± .005, ANGLE ± ½° UNLESS INDICATED OTHERWISE

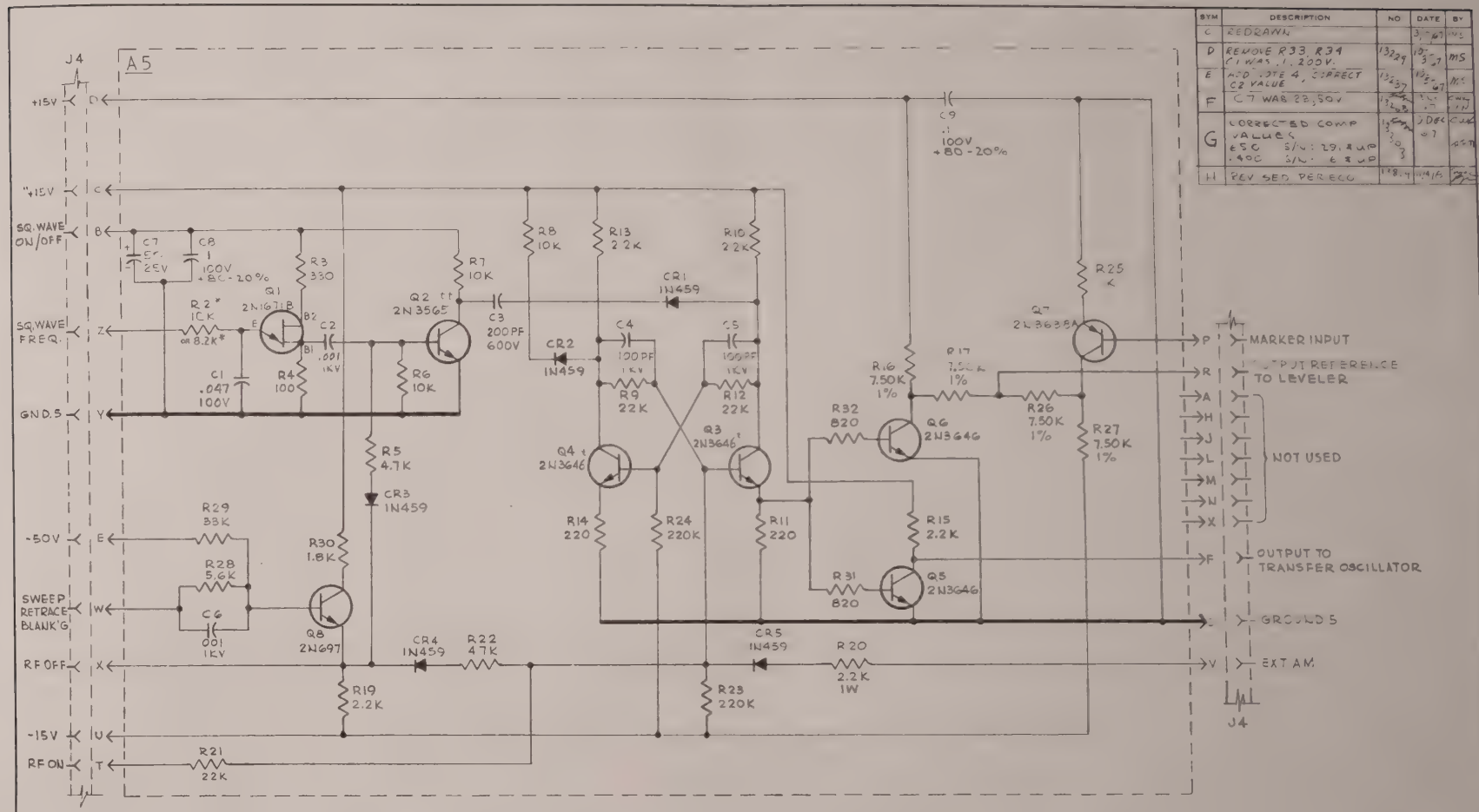
SCHEMATIC MARKERS CIRCUIT A4

950911	6400
950911	6450
NEXT ASSY	USED ON

ALFRED ELECTRONICS
PALO ALTO, CALIFORNIA

SIZE C | 900733 | REV N

SHEET 1 OF 1



SYM	DESCRIPTION	NO	DATE	BY
C	REDRAWN		3-7-67	MS
D	REMOVE R33, R34 C1 WAS .1, 200V.	13229	3-7-67	MS
E	ADD NOTE 4, CORRECT C2 VALUE	13237	3-7-67	MS
F	C7 WAS 22, 50V	13	3-7-67	MS
G	CORRECTED COMP VALUES 650 S/N: 29, & UP 490 S/N: 6 & UP	13	3-7-67	JDG
H	REVISED PER ECO	13	4/4/68	

NOTES:
1. UNLESS OTHERWISE SPECIFIED
   A. ALL RESISTORS ARE IN OHMS, 1/2 W, 10%.
   B. ALL CAPACITORS ARE IN MICROFARADS, ±10%
2. PREFIX REFERENCE DESIGNATORS BY "A5". (i.e., A5 R1, A5 Q6, ETC.)
3. REF. DWGS: ASSEMBLY - ML 950619
   P.C. ARTWORK - C 944050
4. KEY BETWEEN PINS W AND X
5. * FACTORY SELECT
   t 2N3643 IS USED ON SOME UNITS
   tt 2N3646 IS USED ON EARLY UNITS

650 Ser. No. 1651 & up Rev. H

6/69

ITEM	REQD	PART NO	DESCRIPTION

LIST OF MATERIAL

950619	6400
950619	650
NEXT ASSY	USED ON

MATERIAL
MATERIAL STOCK NO.
FINISH OR TREATMENT
SCALE

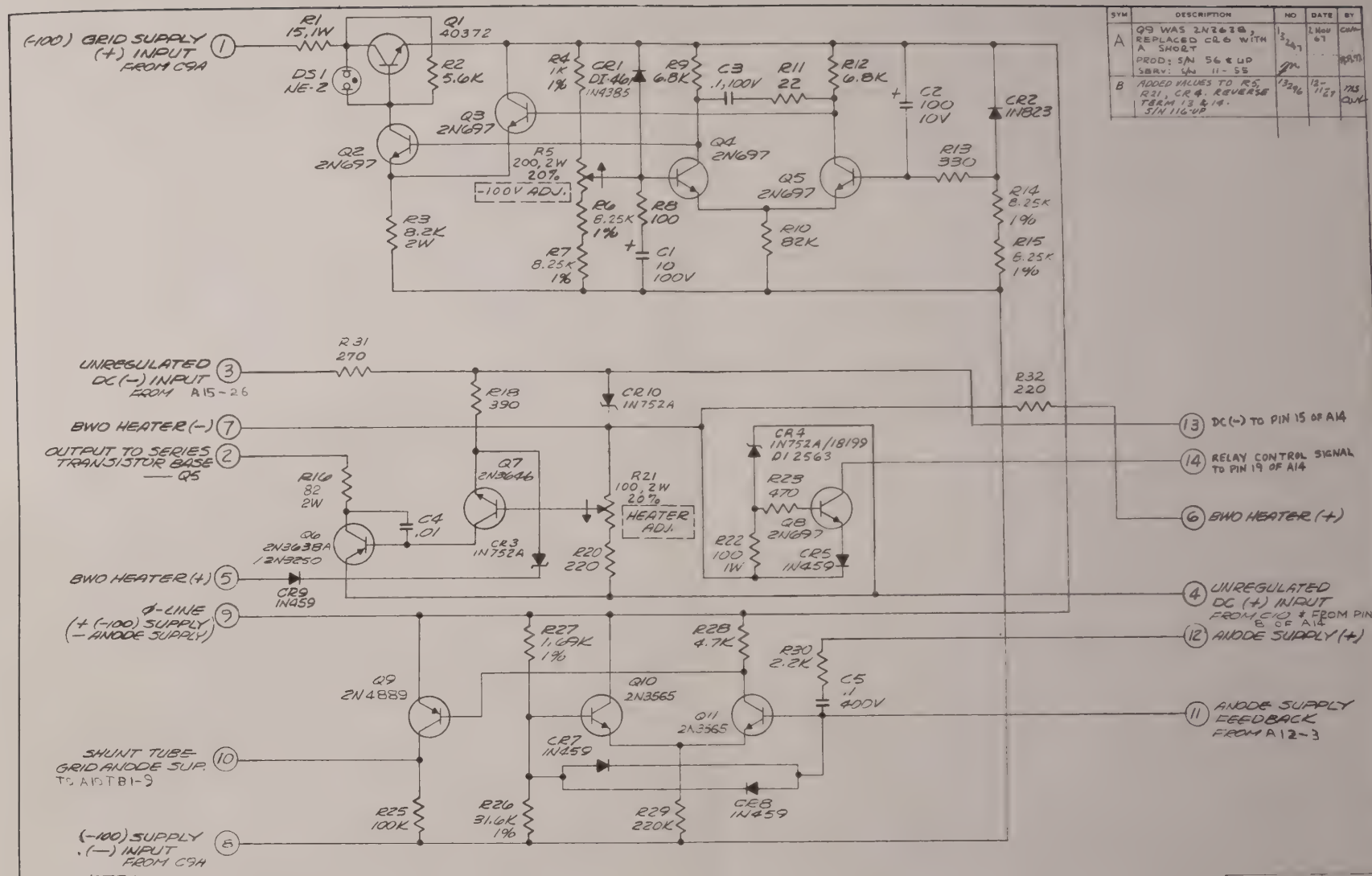
DRAWN I.M. SEEDMAN 3/17/67
ENG
PROD

SCHEMATIC
MODULATION CKT
A5

DIMENSIONS ARE IN INCHES
TOL: .XX ± .01S, .XXX ± .005, ANGLE ± ½°
UNLESS INDICATED OTHERWISE

ALFRED ELECTRONICS
PALO ALTO CALIFORNIA

SIZE C 900714 REV H
SHEET 1 OF 1



SYM	DESCRIPTION	NO	DATE	BY
A	Q9 WAS 2N2672, REPLACED CR6 WITH A SHORT PROD: SN 56 & UP SERV: SN 11-55	132447	2 Nov 67	CWM
B	ADDED VALUES TO R5, R31, CR4. REVERSE TERM 13 & 14. SN 116 UP	132996	12-11-67	TMS CWM

NOTE:

1. UNLESS OTHERWISE SPECIFIED:
   - 1A. ALL RESISTOR IN OHMS, 1/2W 10%
   - 1B. ALL CAPACITOR IN MICROFARADS, 500V
   - 1C. ALL RESISTOR 1% ARE METAL FILMS
2. CIRCLE (◯) DESIGNATES TERMINAL CONNECTION ON ASSY "A6", ASSEMBLY NO. 951096.
3. PREFIX REFERENCE DESIGNATORS BY "A6" (IE: A6R1, A6Q11)

ITEM	REQD	PART NO	DESCRIPTION

LIST OF MATERIAL

951096	6400
NEXT ASSY	USED ON

MATERIAL

MATERIAL STOCK NO

FINISH OR TREATMENT

ENG

SCALE

SCHEMATIC AUXILIARY SUPPLY "A6"

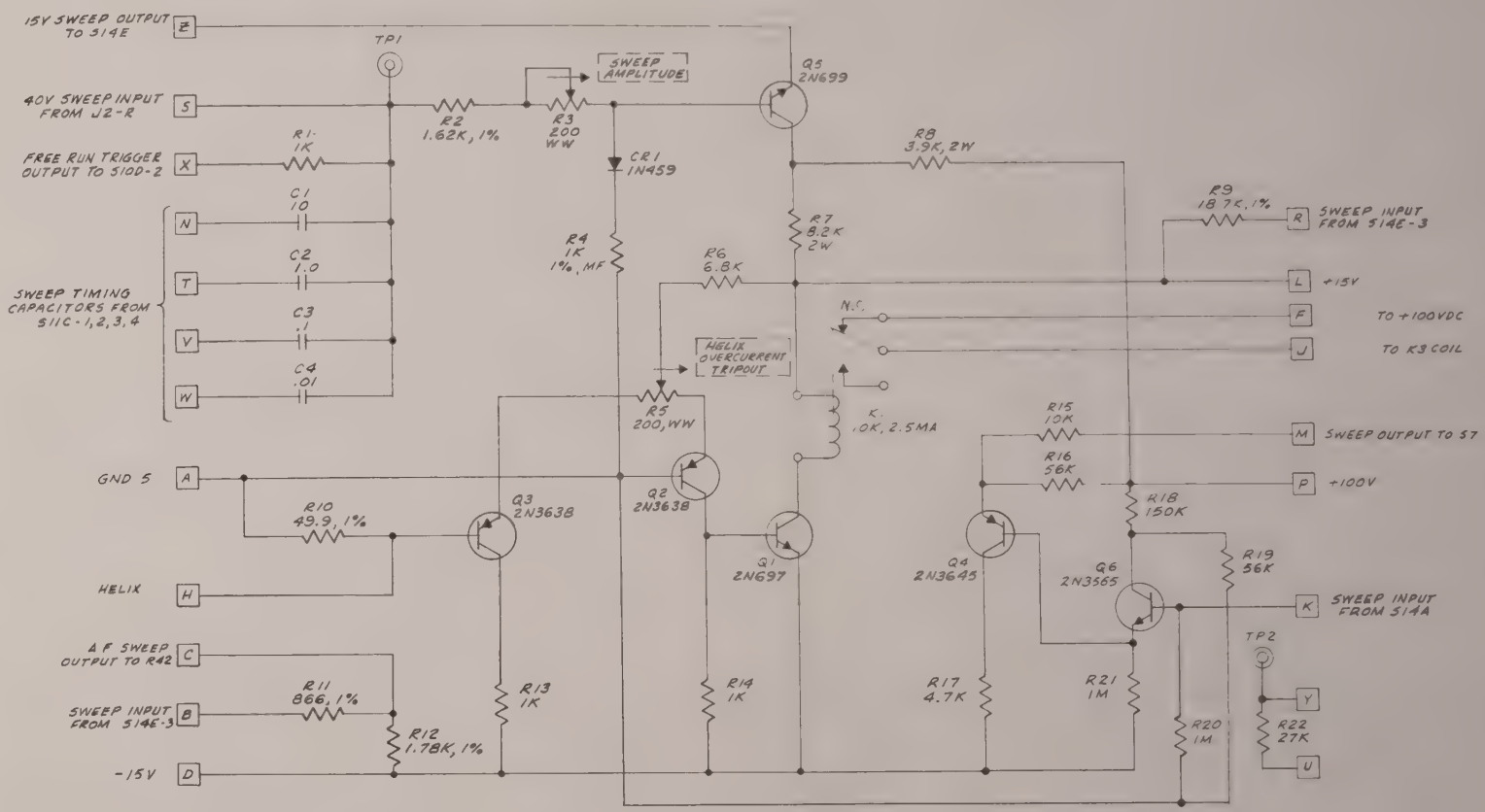
DIMENSIONS ARE IN INCHES
TOL .XX ± .015 .XXX ± .005 ANGLE ± ½
UNLESS INDICATED OTHERWISE

ALFRED ELECTRONICS
PALO ALTO CALIFORNIA

SIZE C 900909 REV B

SHEET / OF /

SYM	DESCRIPTION	NO	DATE	BY



NOTES:

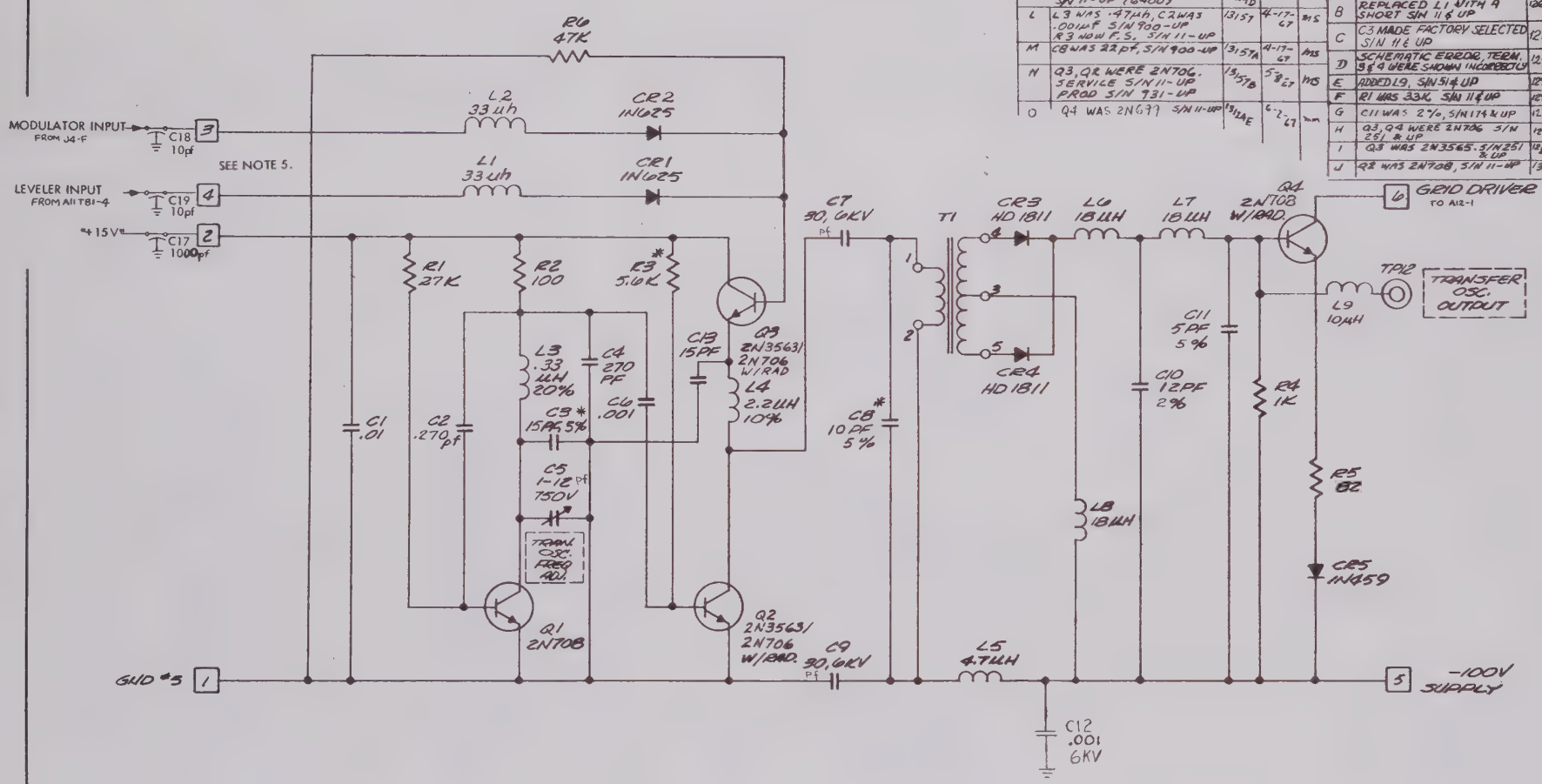
1. UNLESS OTHERWISE SPECIFIED:
   1A. ALL RESISTORS IN OHMS, ½W, ±10%
   1B. ALL CAPACITORS IN MICROFARADS, 500V
2. SQUARES (□) DESIGNATES PRINTED CIRCUIT CONNECTION ON ASSY "A7", ASSEMBLY NO. 901315
3. PREFIX REFERENCE DESIGNATORS BY "A7" (I.E: A7R1, A7Q4)

ITEM	REQD	PART NO.	DESCRIPTION

LIST OF MATERIAL

MATERIAL	DRAWN M. SHEPPARD	DATE 3-5-66	SCHEMATIC HELIX OVERCURRENT
MATERIAL STOCK NO	ENG Jack Johnson	7-13-67	ALFRED ELECTRONICS PALO ALTO CALIFORNIA
FINISH OR TREATMENT	PROD		900843C
	SCALE	DIMENSIONS ARE IN INCHES TOL XX ± .015, XXX ± .005 ANGLE ± ½° UNLESS INDICATED OTHERWISE	SHEET 1 OF 1

6400	
NEXT ASSY	USED ON



SYM	DESCRIPTION	NO.	DATE	BY
K	Q4 WAS 2N708 L2 WAS 10 UH ADD L1 S/N 891-UP (6500) S/N 11-UP (6400)	13124B 13124D	2-9-67	MS
L	L3 WAS .47uH, C2 WAS .001uF S/N 900-UP R3 NOW F.S. S/N 11-UP	13157	4-17-67	MS
M	C8 WAS 22 pF, S/N 900-UP	13157A	4-17-67	MS
N	Q3, Q4 WERE 2N706. SERVICE S/N 11-UP PROD S/N 931-UP	13157B	5-8-67	MS
O	Q4 WAS 2N697 S/N 11-UP	13124E	6-2-67	MS

SYM	DESCRIPTION	NO.	DATE	BY
A	ADDED TP12 & NOMECLATURE ADDED NOMENCLATURE TO C9		3/15/65	cg
B	REPLACED L1 WITH A SHORT S/N 11 & UP	12657	3-26-65	AC
C	C3 MADE FACTORY SELECTED S/N 11 & UP	12719	4-30-65	MN
D	SCHEMATIC ERROR, TERM. 5 & 4 WERE SHOWN INCORRECTLY	12743	6-8-65	JHC
E	ADDED L9, S/N 514 UP	12774	7-23-65	HC
F	R1 WAS 33K, S/N 11 & UP	12780	7-28-65	JHC
G	C11 WAS 2%, S/N 174 & UP	12799	8-17-65	MS
H	Q3, Q4 WERE 2N706 S/N 251 & UP	12831	9-28-65	MS
I	Q3 WAS 2N3565. S/N 251 & UP	12831A	11-22-65	MS
J	Q2 WAS 2N708, S/N 11-UP	13122	2-2-67	MS

NOTES:

1. UNLESS OTHERWISE SPECIFIED:
   - 1A. ALL RESISTOR IN OHMS, 1/2W, 10%
   - 1B. ALL CAPACITOR IN MICROFARADS, 500V
2. SQUARES (□) DESIGNATES TERMINAL CONNECTION ON ASSY "A9", ASSEMBLY NO. 950635
3. PREFIX REFERENCE DESIGNATORS BY "A9" (IE: A9R1, A9Q4)
4. ARTWORK NO. 944056
5. FEEDTHRU CAPACITORS C17, C18, AND C19 ARE NOT PART OF THE TRANSFER OSCILLATOR PC BOARD. THEY ARE MOUNTED ON THE TRANSFER OSCILLATOR BRACKET (903991 REF).

* FACTORY SELECTED

ITEM	REQD	PART NO.	DESCRIPTION

LIST OF MATERIAL

BELOW SER. NO. 112 | 6400

NEXT ASSY | USED ON

MATERIAL

MATERIAL STOCK NO.

FINISH OR TREATMENT

DRAWN Vic Stern DATE 8-18-64

ENG Norman C. Kahn 12-16-64

PROD Allan A. Sullivan 12-15-64

SCALE

SCHEMATIC TRANSFER OSCILLATOR

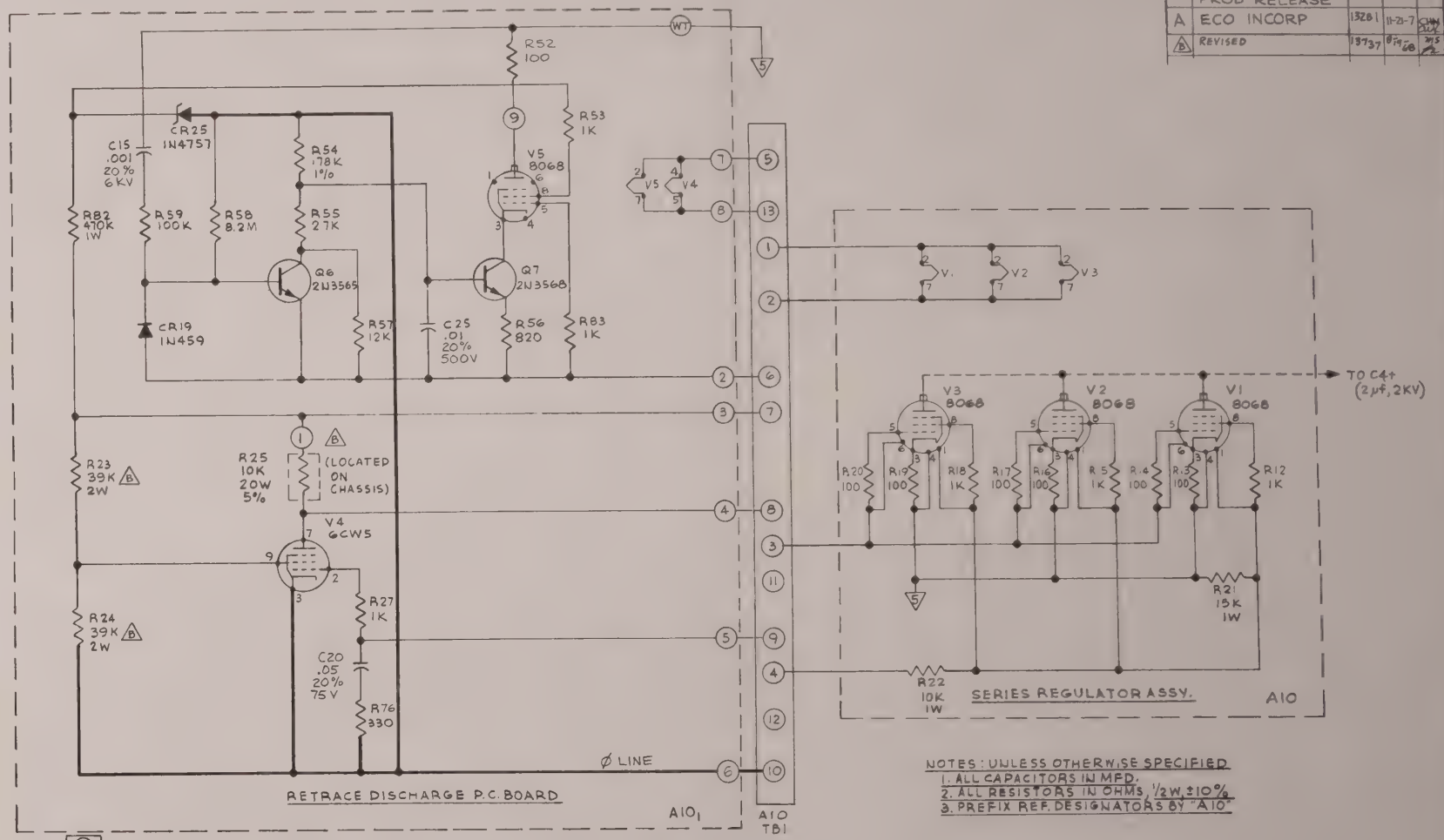
DIMENSIONS ARE IN INCHES
TOL: .XX ± .015, .XXX ± .005, ANGLE ± ½°
UNLESS INDICATED OTHERWISE

ALFRED ELECTRONICS
PALO ALTO, CALIFORNIA REV

C 900747 0

SHEET 1 OF 1

SYM	DESCRIPTION	NO.	DATE	BY
—	PROD RELEASE			
A	ECO INCORP	13281	11-23-7	
B	REVISED	13737	8-19-68	



NOTES: UNLESS OTHERWISE SPECIFIED
1. ALL CAPACITORS IN MFD.
2. ALL RESISTORS IN OHMS, 1/2W, ±10%
3. PREFIX REF. DESIGNATORS BY "A10"

A10 TB1

1	→ T1-6
2	→ T1-5
3	→ A1-D (CATHODE SUPPLY)
4	→ +100V
5	→ T1-16A
6	→ -100V
7	→ A15-19 (RECTIFIER ASSY) & C80+
8	→ A6-12 (AUX SUPPLY
9	→ A6-10 (AUX. SUPPLY)
10	→ A6-9 (AUX. SUPPLY) & C80-, & A15-18 (RECTIFIER ASSY)
11	
12	
13	→ T1-16

Ser. No. 1571 & up Rev B

ITEM	REQD	PART NO	DESCRIPTION

LIST OF MATERIAL

951082	6400,650
951083	6400,650
NEXT ASSY	USED ON

MATERIAL

DRAWN I M SEEDMAN DATE 5/9/67
ENG T. Tolmie 11/24/67
PROD

MATERIAL STOCK NO

FINISH OR TREATMENT

SCALE —

SCHEMATIC SERIES REGULATOR/RETRACE DISCHARGE ASSY. "A10"

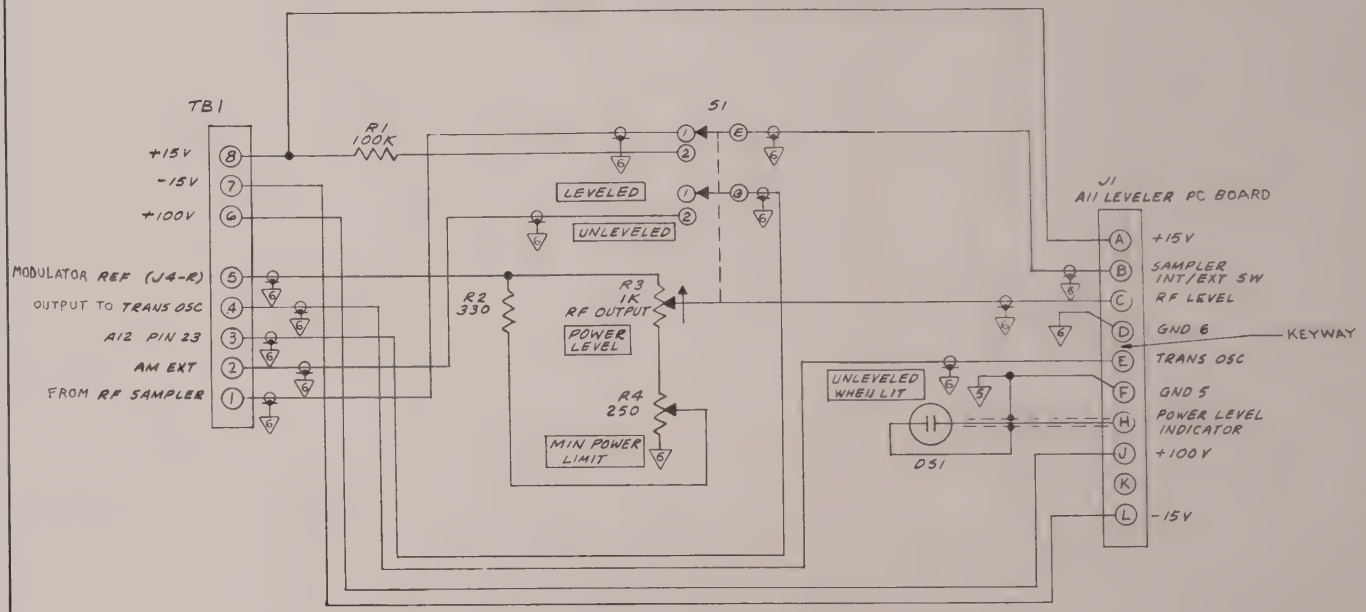
DIMENSIONS ARE IN INCHES
TOL .XX ± .018, .XXX ± .005 ANGLE ± ½°
UNLESS INDICATED OTHERWISE

ALFRED ELECTRONICS
PALO ALTO CALIFORNIA

SIZE C | 900906 | REV B

SHEET 1 OF 1

SYM	DESCRIPTION	NO.	DATE	BY
–	PROD. RELEASE		8-24-7[illegible]	R M



NOTES:

1. UNLESS OTHERWISE SPECIFIED:
   1A. RESISTORS ARE IN OHMS, ½ W, 10%
2. PREFIX REFERENCE DESIG. BY "A11"; ASSY NO. 901505

ITEM	REQD	PART NO.	DESCRIPTION
			LIST OF MATERIAL

MATERIAL

MATERIAL STOCK NO.

FINISH OR TREATMENT

DRAWN M. SHEPPARD DATE 5-24-'66

ENG

PROD

SCALE

INTERCONNECTION SCHEMATIC GRID LEVELED CKT "A11"

DIMENSIONS ARE IN INCHES
TOL .XX ± .015 .XXX ± .005 ANGLE ± ½°
UNLESS INDICATED OTHERWISE

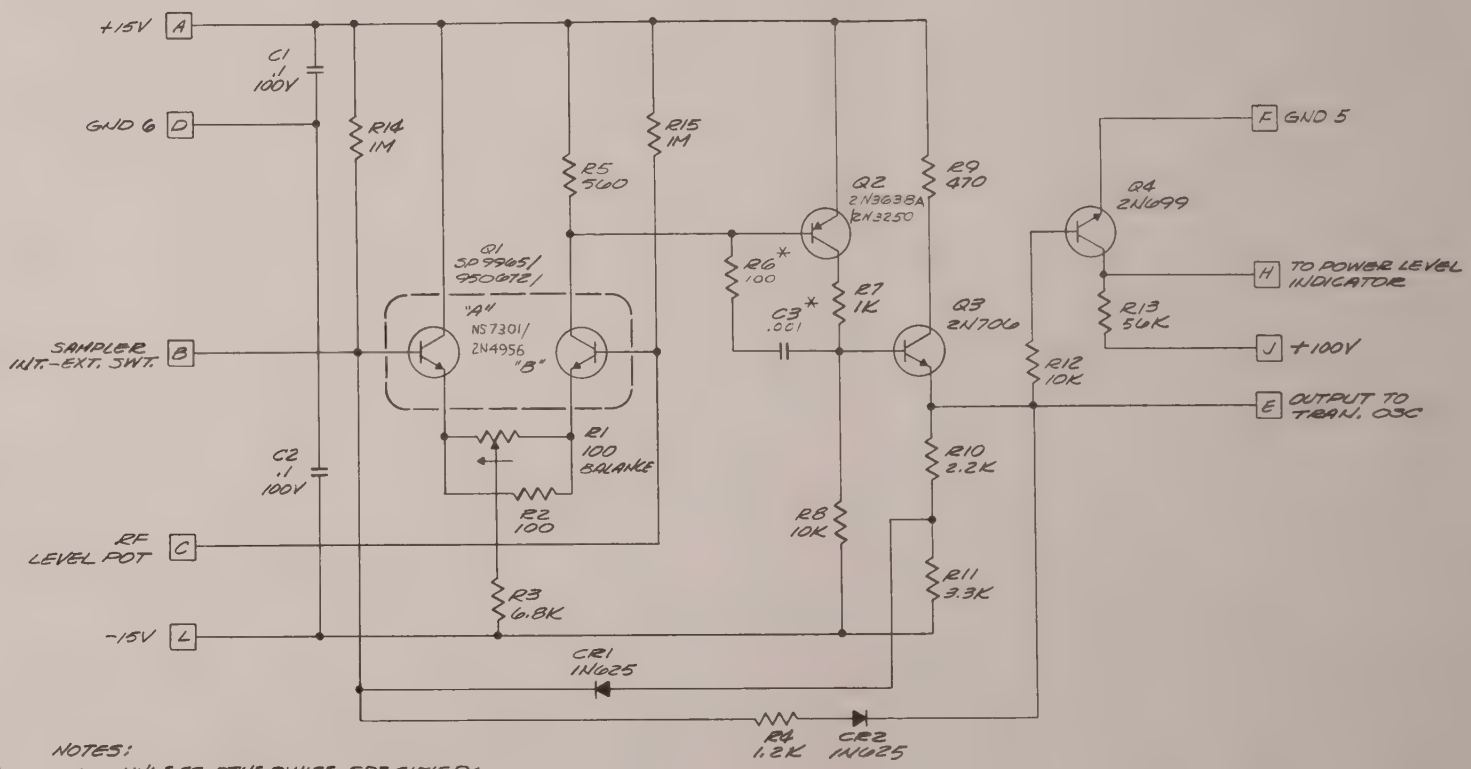
ML 901505 | 6400
NEXT ASSY | USED ON

ALFRED ELECTRONICS
PALO ALTO CALIFORNIA

SIZE C | 900872 | REV –

SHEET | OF | PUBS

SYM	DESCRIPTION	NO.	DATE	BY
A	Q2 WAS 2N3250	12632	2-6-65	CG
B	REMOVED NOTE 4 R6 & C3 MADE FACTOR SEL.	12642	2-15-65	CG



NOTES:

1. UNLESS OTHERWISE SPECIFIED:
   1A. ALL RESISTORS IN OHMS, 1/2W, 10%
   1B. ALL CAPACITORS IN MICROFARADS, 500V
2. SQUARES (□) DESIGNATES PRINTED CIRCUIT CONNECTION ON ASSY "A11", ASSY NO. 950621
3. PREFIX REFERENCE DESIGNATORS BY "A11" (I.E.: A11R1, A11Q4)

* FACTORY SELECTED

6/69

ITEM	REQD	PART NO.	DESCRIPTION
			LIST OF MATERIAL

S/N 11	6521-34
SER NO. 11 & UP	650
NEXT ASSY	USED ON

MATERIAL —

MATERIAL STOCK NO —

FINISH OR TREATMENT —

DRAWN Vic Itow 9/13/64

ENG 1-4-65

PROD 1-11-65

SCALE —

SCHEMATIC LEVELER AMPLIFIER (GRID LEVEL)

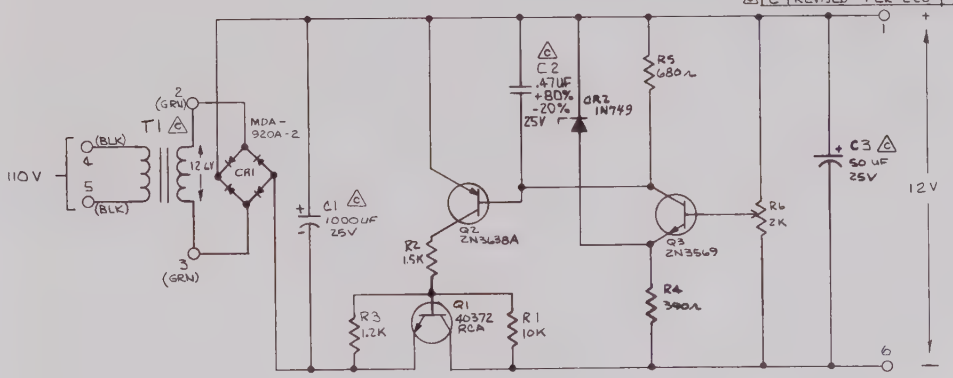
DIMENSIONS ARE IN INCHES
TOL: .XX ± .015, .XXX ± .005, ANGLE ± ½°
UNLESS INDICATED OTHERWISE

ALFRED ELECTRONICS
PALO ALTO, CALIFORNIA

900730C

SHEET 1 OF 1

SYM	DESCRIPTION	NO	DATE	BY
-	PRODUCTION RELEASE		11-28-67	LH
A	CHANGED R1 & R3, ADDED NOTE 1	13422	2-2-68	LH
B	REVISED PER ECO	13509	4-16-68	CLM
C	REVISED PER ECO	14008	7-10-68	CLM



NOTES

1. ALL RESISTANCE VALUES IN OHMS, ±5%, ½W.
2. CIRCLES INDICATE TERMINALS ON PW BOARD.

ITEM	REQD	PART NO	DESCRIPTION
			LIST OF MATERIAL

	951087	6400
	951087	650 PLUG-IN
	NEXT ASSY	USED ON

MATERIAL

MATERIAL STOCK NO

FINISH OR TREATMENT

		DATE
DRWN	[illegible]	4-28-67
ENG	T Russell	11-29-67
PROD	[illegible]	11-28-67

SCALE

12V SUPPLY

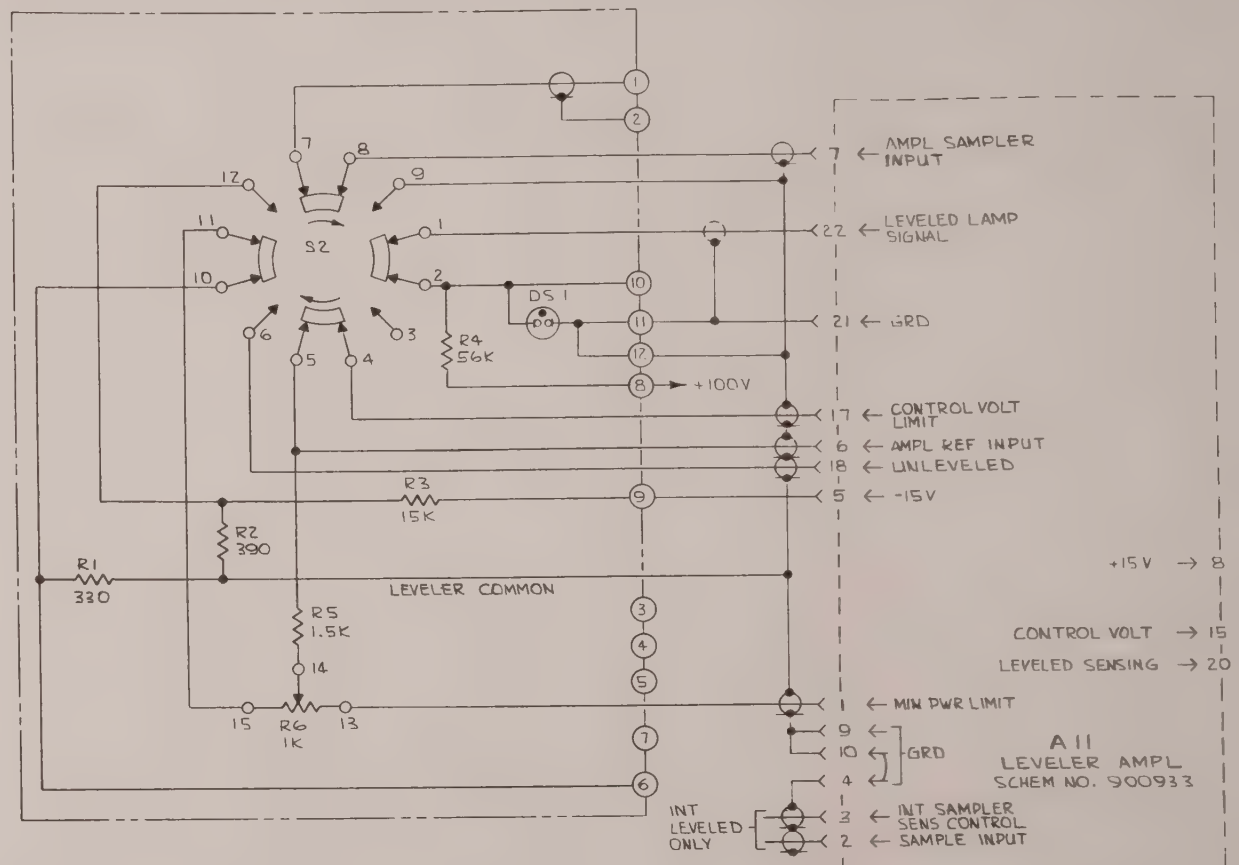
DIMENSIONS ARE IN INCHES
TOL .XX ± .015 .XXX ± .005 ANGLE ± ½°
UNLESS INDICATED OTHERWISE

ALFRED ELECTRONICS
PALO ALTO CALIFORNIA

SIZE		REV
B	900930	C

SHEET 1 OF 1

SYM	DESCRIPTION	NO.	DATE	BY
-	PROD RELEASE	307		



NOTES:

1. ALL RESISTANCE VALUES IN OHMS, ±5%, ½W.
2. S2 SHOWN IN CCW POSITION VIEWED FROM KNOB END.

ITEM	REQD	PART NO.	DESCRIPTION
			LIST OF MATERIAL

901504	6400
NEXT ASSY	USED ON

MATERIAL —

MATERIAL STOCK NO —

FINISH OR TREATMENT —

DRAWN — DATE 2-7-63

ENG — 6-5-63

PROD

CKD — 6-7-63

SCALE —

SCHEMATIC
PIN DIODE LEVELER

DIMENSIONS ARE IN INCHES
TOL XX ± .015 XXX ± .005 ANGLE ± ½°
UNLESS INDICATED OTHERWISE

ALFRED ELECTRONICS
PALO ALTO CALIFORNIA

SIZE C | 907055 | REV

SHEET 1 OF 1

TABLE OF VOLTAGE MEASUREMENTS ON LEVELER-AMPLIFIER A11 PC BOARD

TEST POINT	LOCATION		MEASUREMENT CONDITION (Operating Mode)* & MEASURED VOLTAGES (All Measurements in Volts)			
			LEVELED		UNLEVELED	
			a*	b*	c*	d*
A	Q1A	Base	- .073	- .018	- .011	- .011
B	Q1B	Base	- .062	- .008	0	0
C	Q3	Base	+ 2.33	+ 2.35	+2.34	+2.34
D	Q4	Base	+ 2.40	+ 2.39	+2.39	+2.39
E	Q5	Base	- 8.57	- 8.66	-8.63	-8.72
F	Q7	Base	+ 3.92	+ 4.56	+4.32	+4.95
G	Q8B	Base	+ 0.16	+ 4.68	+4.76	+4.76
H	Q10 and Q11	Base	- 1.57	- 1.89	-1.09	-2.75
J	Q11	Emitter	- 0.91	- 1.23	-0.43	-2.07
K	CR2	Cathode	+ 0.56	+ 0.29	+1.00	-0.49
L	PIN 18		- 0.52	- 0.53	+1.00	-0.48
M	Q12	Base	- 3.72	- 4.39	-3.43	-3.79
N	Q12	Emitter	- 1.08	- 0.80	+0.08	+0.10
O	Q14	Base	- 0.46	- 0.19	+0.01	+0.52
P	Q14	Collector	+21.5	+21.6	0	+0.05

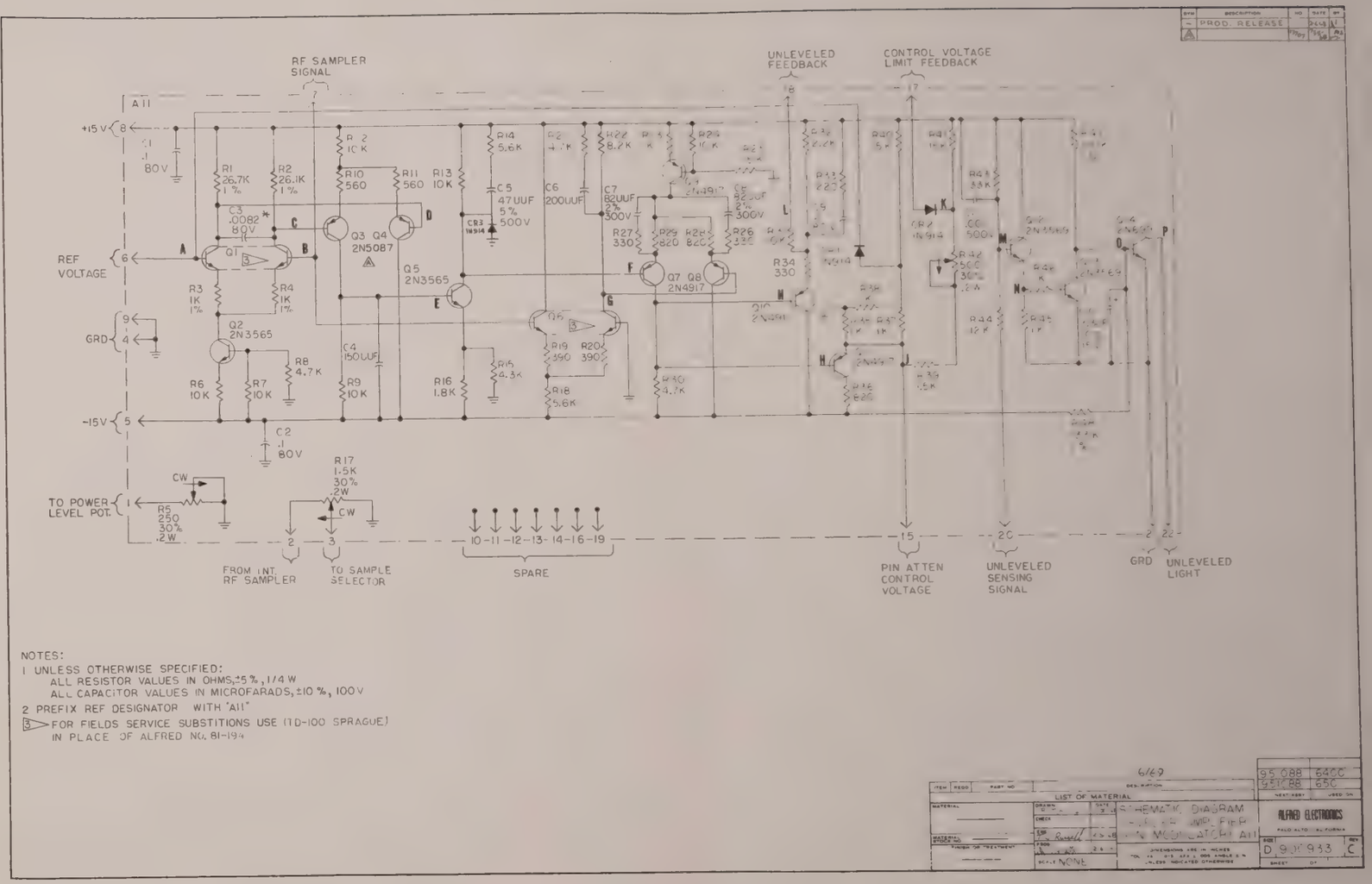
* DC VOLTAGES SHOWN ARE TYPICAL, MEASURED WITH RESPECT TO CHASSIS GROUND DURING SINGLE-FREQUENCY OPERATION, USING A HIGH-IMPEDANCE DIGITAL METER. AN ATTENUATOR OR OTHER SUITABLE LOAD SHOULD BE CONNECTED TO THE RF OUTPUT JACK.

a. Measured in LEVELED mode with POWER LEVEL control set at the mid-band point which provides maximum power with full-band leveling. (this point can be found by adjusting the POWER LEVEL control to the point where the UNLEVELED light is turned off during full-band sweep before switching to single-frequency operation for measurements.)

b. Measured in LEVELED mode with POWER LEVEL control fully CCW (minimum power).

c. Measured in UNLEVELED mode with POWER LEVEL control fully CW (maximum power).

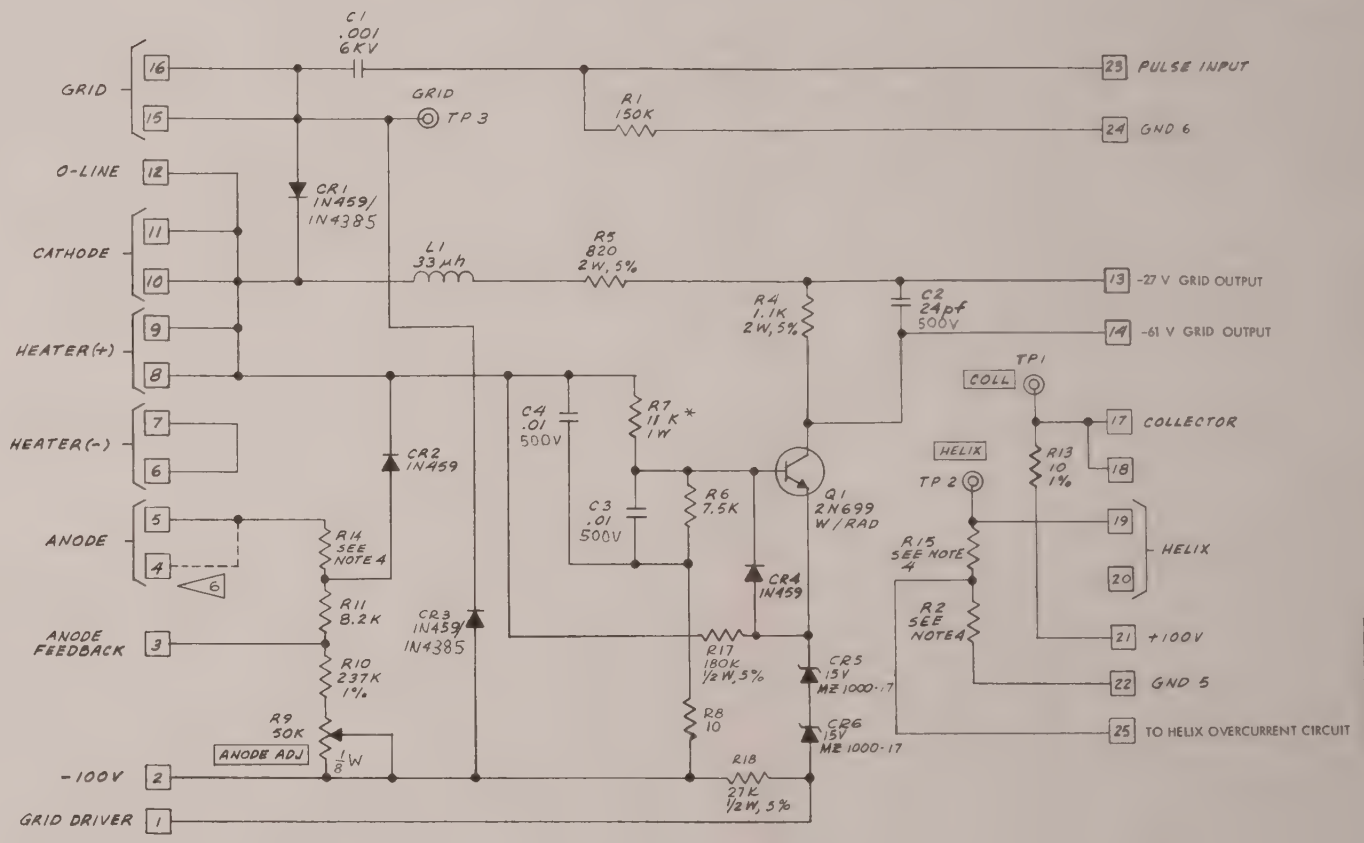
d. Measured in UNLEVELED mode with POWER LEVEL control fully CCW (minimum power).



NOTES:
1 UNLESS OTHERWISE SPECIFIED:
ALL RESISTOR VALUES IN OHMS, ±5%, 1/4 W
ALL CAPACITOR VALUES IN MICROFARADS, ±10%, 100V
2 PREFIX REF DESIGNATOR WITH "A11"
3 FOR FIELDS SERVICE SUBSTITIONS USE (TD-100 SPRAGUE) IN PLACE OF ALFRED NO. 81-194

6/69		95 088	6400
		95 088	650
LIST OF MATERIAL		SCHEMATIC DIAGRAM LEVELER-AMPLIFIER MODULATOR A11	
		ALFRED ELECTRONICS PALO ALTO CALIFORNIA	
SCALE NONE		SIZE D	90 933 REV C

SYM	DESCRIPTION	NO	DATE	BY
A	CKT REVISED REFER TO ECO	13118A	3-8-67	MS
B	CKT REVISED REFER TO ECO	13175	5/26/67	MS
C	ADDED NOTE 6	13245	10-18-67	[illegible]



REFERENCE DESIGNATIONS		
FIRST	LAST	NOT USED
C1	C4	
CR1	CR6	
L1	L1	
Q1	Q1	
R1	R18	P3, R12, R16

NOTES:

1. UNLESS OTHERWISE SPECIFIED:
   1a. ALL RESISTORS IN OHMS, $\frac{1}{2}$ W, 10%
   1b. ALL RESISTORS VALUED 1% ARE METAL FILM.
   1c. ALL CAPACITORS IN MICROFARADS, 500V
2. SQUARES (□) DESIGNATE TERMINAL CONNECTIONS ON ASSY "A12" ASSEMBLY NO. 901488.
3. PREFIX REFERENCE DESIGNATORS BY "A12" (I.E.: A12R1, A12Q1)
4. REFER TO INSTRUCTION MANUAL.
5. ASSY P.C. BD. NUMBER IS 944126C

<6> ON INSTRUMENTS USING THE ANODE PROTECTION CIRCUIT 951155, THE CONNECTION BETWEEN A12-4 & A12-5 IS BROKEN.

ITEM	REQD	PART NO.	DESCRIPTION

LIST OF MATERIAL

901488	K'S 19974-L	
901488	650 PLUG-IN	
901488	6400	
NEXT ASSY	USED ON	

MATERIAL

MATERIAL STOCK NO

FINISH OR TREATMENT

DRAWN	M. SHEPPARD	11-27-67
ENG	[illegible]	5/4/67
PROD		
SCALE		

SCHEMATIC ELEVATED SUPPLY 650-3-4-5 6400

DIMENSIONS ARE IN INCHES
TOL .XX ± .015, .XXX ± .005 ANGLE ± ½° UNLESS INDICATED OTHERWISE

ALFRED ELECTRONICS
PALO ALTO CALIFORNIA

SIZE C | 900869 | REV G

SHEET 1 OF 1

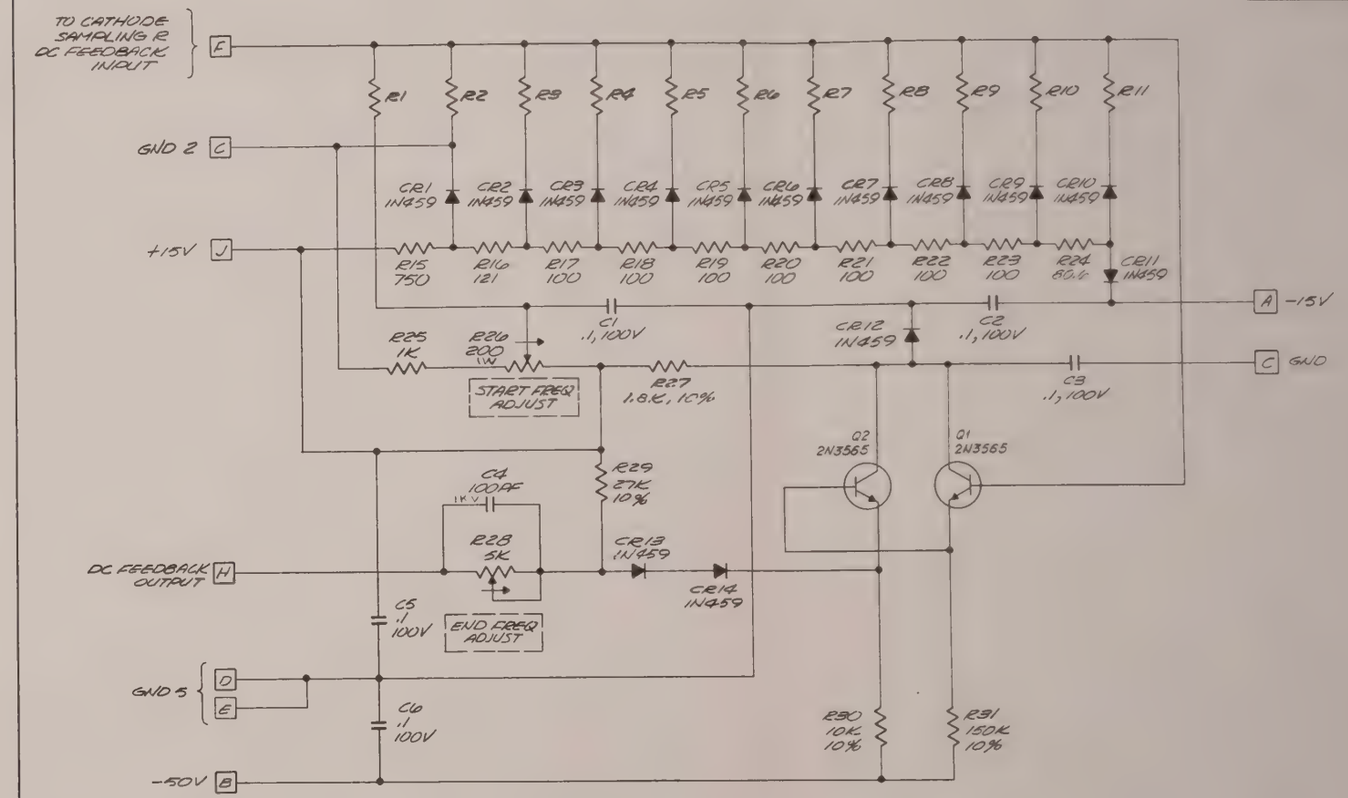
Table of Resistor Values for the Diode Shaper Assembly

Frequency GHz.	6400 Model No.	650 Model No.	Tube Manufacturer	Alfred Tube No.	Diode Shaper PC Board	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
1 to 2	6410 thru 6415	651 651K 651C 651CK	Stewart	112-029	950636	124K	165K	499K	475K	357K	562K	432K	422K	866K	261K	576K
1.4 to 2.5	6410-1 thru 6415-1	651-S1 651K-S1 651C-S1 651CK-S1	Stewart	112-034	950637	107K	340K	442K	576K	887K	412K	464K	1.15M	374K	412K	1.15M
1.7 to 4.2	6420-1 thru 6423-1	652-S5 652K-S5 652C-S5 652CK-S5	Stewart	112-033	950858	178K	102K	280K	261K	205K	187K	210K	154K	147K	137K	162K
2 to 4	* 6420 thru 6425	* 652 652K 652C 652CK	Watkins-Johnson Varian	112-095 112-015	951877 951601	107K 215K	750K 274K	750K 953K	309K 887K	422K 536K	348K 604K	287K 619K	536K 634K	267K 562K	392K 487K	383K 634K
3.5 to 6.75	6430-1 thru 6435-1	653-S1 653K-S1 653C-S1 653CK-S1	Stewart Varian	112-035 112-016	950640 951602	100K 226K	121K 340K	402K 768K	383K 909K	243K 866K	301K 649K	237K 576K	374K 649K	130K 562K	340K 562K	174K 453K
3.7 to 8.3	6430-2 thru 6433-2	653-S2 653K-S2 653C-S2 653CK-S2	Stewart Varian	112-028 112-017	950965 951610	158K 205K	110K 147K	316K 402K	261K 374K	226K 324K	221K 294K	178K 267K	165K 237K	154K 165K	124K 412K	110K 140K
4 to 8	6430 thru 6435	653 653K 653C 653CK	Stewart Varian	112-027 112-006	950639 950932	133K 215K	133K 196K	392K 499K	340K 357K	294K 324K	274K 287K	243K 261K	215K 215K	200K 178K	187K 143K	154K 143K
7 to 11	6440 thru 6443	654 654K 654C 654CK	Varian Watkins-Johnson	112-012 112-039	950641 951699	187K 86.6K	866K 576K	976K 806K	1.15M 549K	1.02M 866K	953K 442K	649K 665K	698K 523K	634K 324K	576K 619K	499K 422K
7 to 12.4	6440-1 thru 6443-1	654-S1 654K-S1 654C-S1 654CK-S1	Varian Watkins-Johnson	112-012 112-039	950647 951603	191K 82.5K	274K 154K	619K 357K	536K 357K	475K 301K	402K 301K	365K 255K	316K 243K	249K 215K	249K 200K	169K 182K
8 to 12.4	6450 thru 6453	655 655K 655C 655CK	Varian Watkins-Johnson	112-013 112-038	950642 951604	133K 634K	465K 340K	715K 453K	649K 464K	549K 442K	536K 365K	475K 324K	392K 442K	357K 267K	294K 324K	280K 243K
10 to 15.5	6460	656	Varian	112-014	950643	137K	549K	750K	715K	487K	536K	619K	453K	499K	549K	249K
12.4 to 18	6470 6471	657 657K	Varian	112-009	950644	133K	—	1.40M	768K	1.40M	604K	866K	536K	590K	715K	604K
18 to 26.5	6480	658	Varian	112-010	950645	150K	1.40M	1.24M	953K	909K	750K	825K	634K	649K	442K	324K
26.5 to 40	6490	659	Varian	112-011	950646	110K	464K	634K	619K	549K	475K	442K	392K	294K	357K	243K

* 650

Frequency GHz.	6400 Model No.	650 Model No.	Tube Manufacturer	Tube No.	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
2 to 4	6420 thru 6425	ALT. SHAPER 950638 652 652K 652C 652CK	ALT. TUBE Stewart	SE 2154-2	124K	133K	383K	332K	340K	280K	301K	267K	232K	221K	232K

*



SYM	DESCRIPTION	NO	DATE	BY
A	Q1 & Q2 REPLACED Q1A + Q1B S/N 30 & UP	12700	4-15-65	MN
B	SCHEMATIC ERROR R27 WAS SHOWN AS 1.5K	12778	7-19-66	JAC

NOTES:

1. UNLESS OTHERWISE SPECIFIED:
   - 1A. ALL RESISTORS IN OHMS, ½W, 1% METAL FILM
   - 1B. ALL CAPACITORS IN MICROFARADS
2. REFER TO INSTRUCTION MANUAL FOR SPECIFIC VALUE OF R1 THRU R11 FOR THE PARTICULAR MODEL INVOLVED
3. SQUARES (□) DESIGNATE PRINTED CIRCUIT CONNECTION ON ASSY NO. 950---
4. PREFIX REFERENCE DESIGNATORS BY "A1B" (I.E: A1BR1, A1BQ2)

ITEM	REQD	PART NO.	DESCRIPTION

LIST OF MATERIAL

S/N 11-UP	650	
NEXT ASSY	USED ON	

MATERIAL ——

MATERIAL STOCK NO. ——

FINISH OR TREATMENT ——

	DRAWN	DATE
	D. Stone	1-4-65
ENG.	Hans Schwarz	1-4-65
PROD	W. Kirkland	1-11-65

SCALE ——

SCHEMATIC DIODE SHAPER

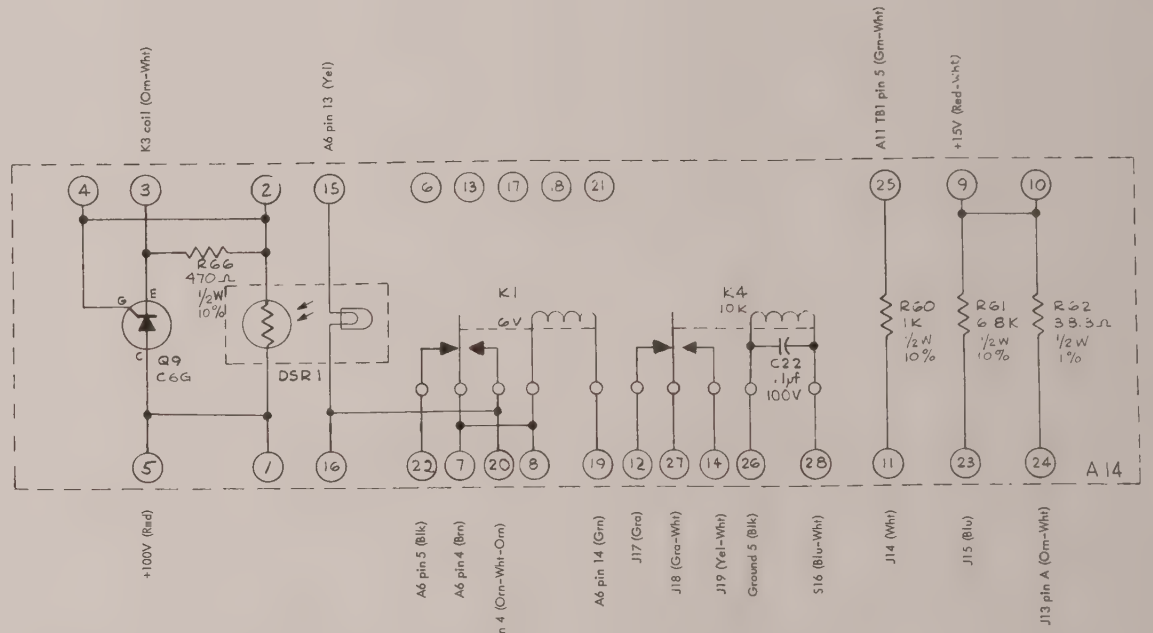
DIMENSIONS ARE IN INCHES
TOL .XX ± .015 .XXX ± .005 ANGLE ± ½°
UNLESS INDICATED OTHERWISE

ALFRED ELECTRONICS
PALO ALTO CALIFORNIA

900713C

SHEET / OF /

SYM	DESCRIPTION	NO	DATE	BY
-	PROD. RELEASE		8-24-7	RM
A	CORRECT SCH ERRORS. S/N: 16# UP	13279	21 Nov 67	CWK CAN



NOTES:

1. PREFIX REF. DESIGNATORS BY "A14" (i.e., A14 K1, A14 DSR1, ETC.)
2. TERMINALS NOT HAVING AN EXTERNAL CONNECTION SHOWN ARE NC.

ITEM	REQD	PART NO.	DESCRIPTION
			LIST OF MATERIAL

MATERIAL

MATERIAL STOCK NO.

FINISH OR TREATMENT

DRAWN I.M. SEEDMAN 5/8/67

ENG

PROD

SCALE —

SCHEMATIC
PROT. CKT/AUX. SIGNAL BD.
A14

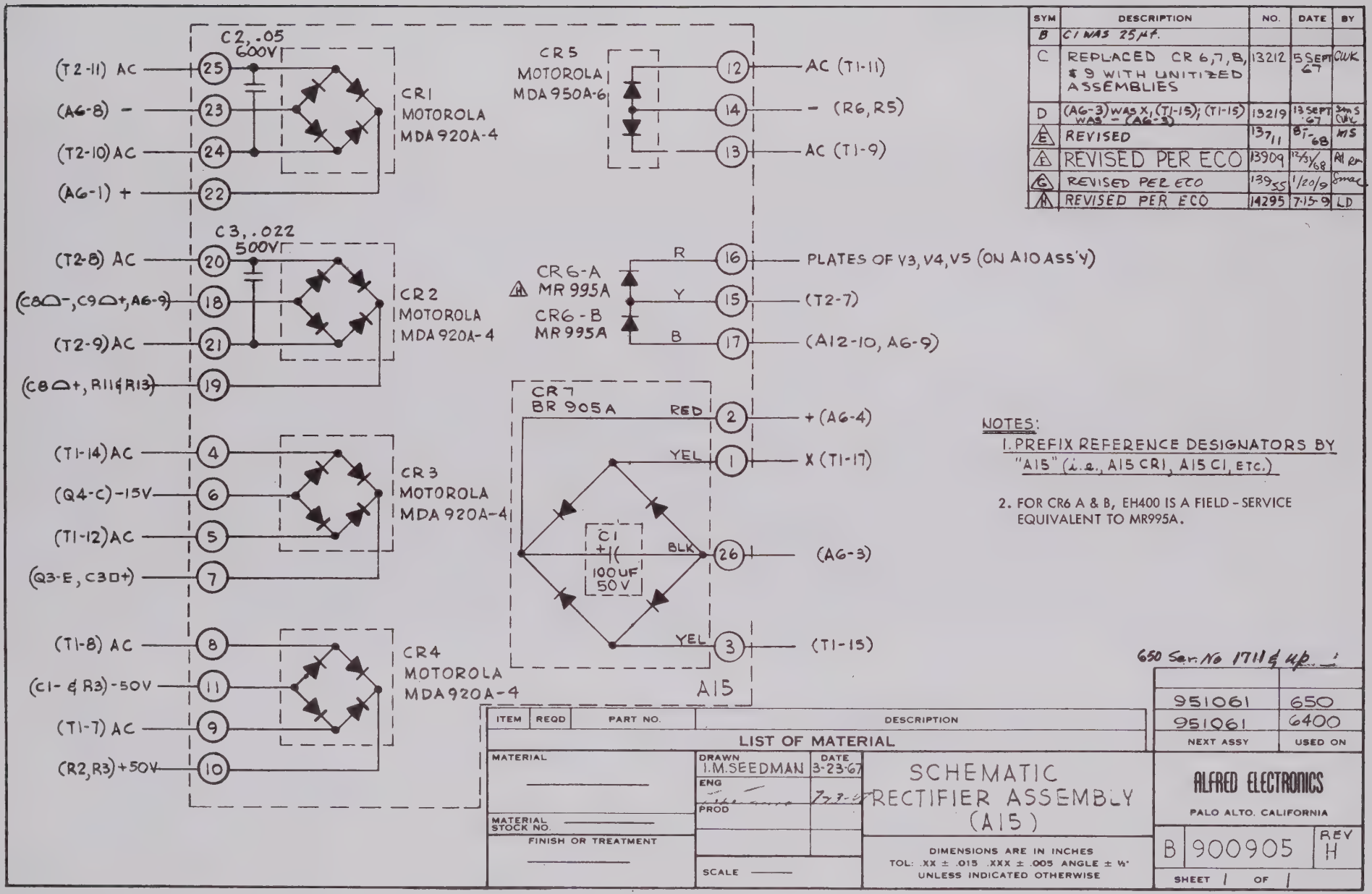
DIMENSIONS ARE IN INCHES
TOL. .XX ± .01S, .XXX ± .00S, ANGLE ± ½°
UNLESS INDICATED OTHERWISE

951137	6400
NEXT ASSY	USED ON

ALFRED ELECTRONICS
PALO ALTO CALIFORNIA

SIZE		REV
C	900910	A

SHEET 1 OF 1



SYM	DESCRIPTION	NO.	DATE	BY
B	C1 WAS 25 μf.			
C	REPLACED CR 6, 7, 8, & 9 WITH UNITIZED ASSEMBLIES	13212	5 SEPT 67	CWK
D	(AG-3) WAS X, (T1-15); (T1-15) WAS - (AG-3)	13219	13 SEPT 67	JMS CWK
E	REVISED	13711	8-68	MS
F	REVISED PER ECO	13909	12/31/68	RM RP
G	REVISED PER ECO	13955	1/20/69	JMS
H	REVISED PER ECO	14295	7-15-69	LD

NOTES:

1. PREFIX REFERENCE DESIGNATORS BY "A15" (i.e., A15 CR1, A15 C1, ETC.)
2. FOR CR6 A & B, EH400 IS A FIELD-SERVICE EQUIVALENT TO MR995A.

650 Ser. No 1711 & up.

ITEM	REQD	PART NO.	DESCRIPTION

LIST OF MATERIAL

951061	650
951061	6400
NEXT ASSY	USED ON

MATERIAL

MATERIAL STOCK NO.

FINISH OR TREATMENT

DRAWN	I.M.SEEDMAN	DATE 3-23-67
ENG		
PROD		

SCALE

SCHEMATIC RECTIFIER ASSEMBLY (A15)

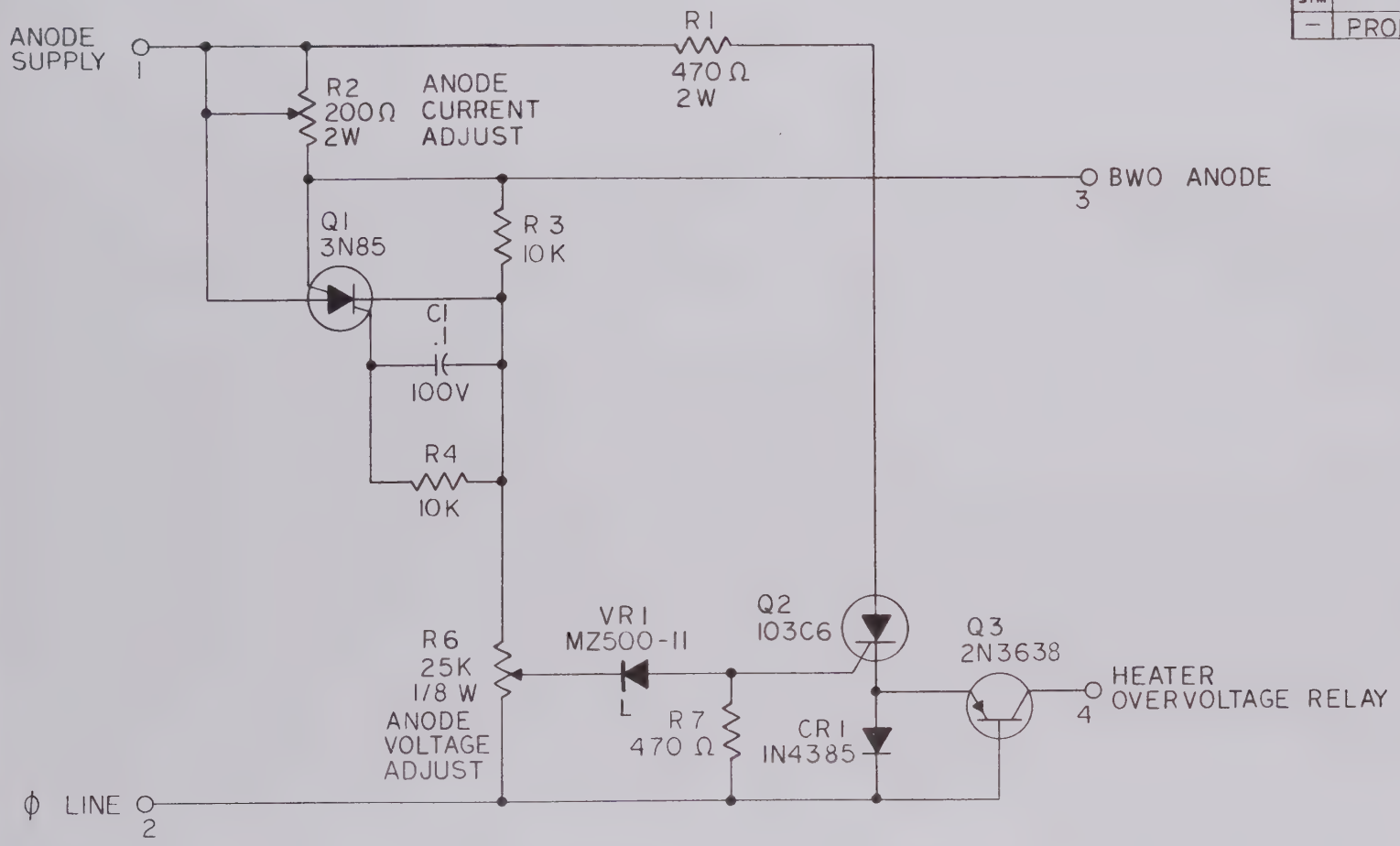
DIMENSIONS ARE IN INCHES
TOL: .XX ± .015 .XXX ± .005 ANGLE ± ½°
UNLESS INDICATED OTHERWISE

ALFRED ELECTRONICS
PALO ALTO, CALIFORNIA

B 900905 REV H

SHEET 1 OF 1

SYM	DESCRIPTION	NO.	DATE	BY
–	PROD RELEASE	13241	10-10-67	CWK



NOTE:
1. ALL RESISTOR VALUE IN OHMS, ±10 %, 1/2 W.
2. PREFIX REF DES WITH A19.
3. R5 NOT USED.

ITEM	REQD	PART NO.	DESCRIPTION

LIST OF MATERIAL

951155	950776
951155	950771
951155	950736
951155	630
951155	6400
NEXT ASSY	USED ON

MATERIAL

MATERIAL STOCK NO

FINISH OR TREATMENT

DRAWN Chuck Koehler 4 Oct 67 | DATE

ENG

PROD

SCALE

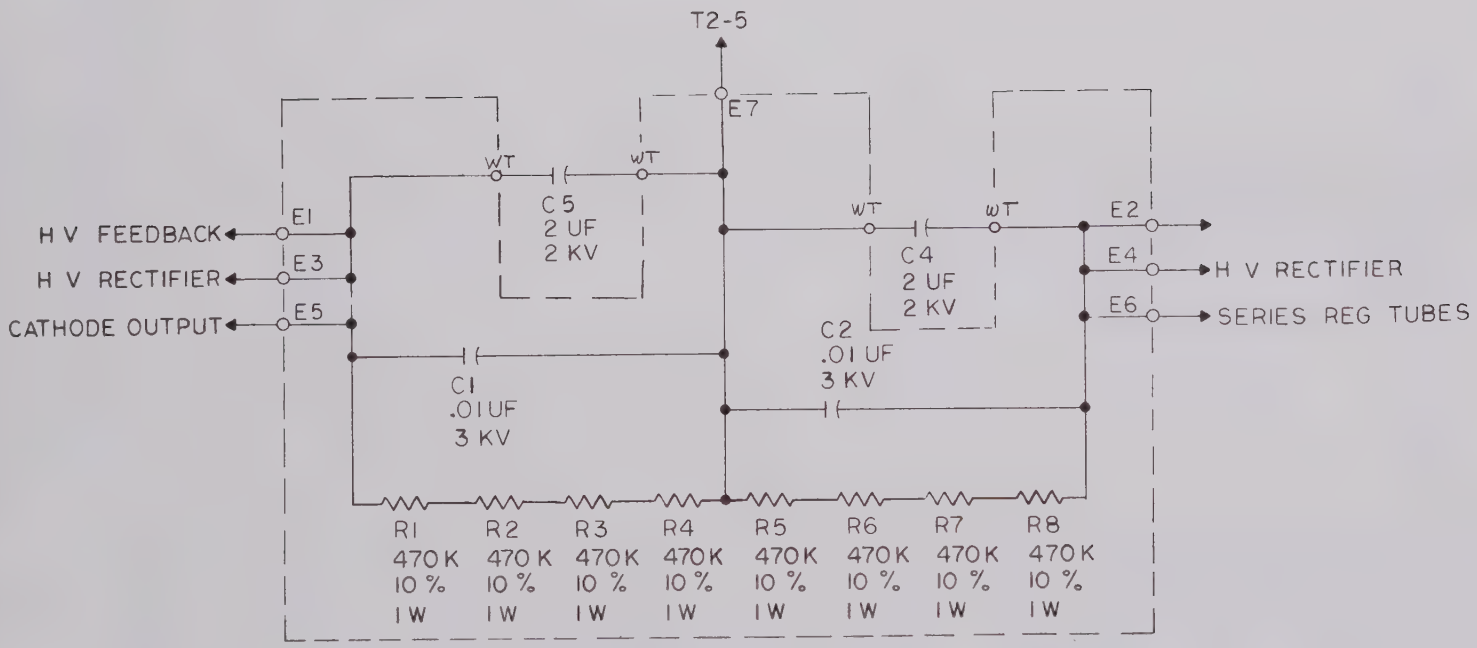
SCHEMATIC
ANODE PROTECTION CKT

DIMENSIONS ARE IN INCHES
TOL: XX ± .015 XXX ± .005 ANGLE ± ½
UNLESS INDICATED OTHERWISE

ALFRED ELECTRONICS
PALO ALTO, CALIFORNIA

SIZE		REV
B	900940	—

SHEET 1 OF 1



650 Ser. No. 1251 & up

951249	KS 19974-L1
951249	6400
951249	650
951249	650 RETROFIT
NEXT ASSY	USED ON

ITEM	REQD	PART NO.	DESCRIPTION
			LIST OF MATERIAL

MATERIAL

MATERIAL STOCK NO.

FINISH OR TREATMENT

DRAWN	A. Dowy	DATE 9-26-67
ENG		
PROD	J. Kovall	10-18-67
CHK		

SCALE NONE

SCHEMATIC DIAGRAM
INPUT FILTER - BLEEDER A26

DIMENSIONS ARE IN INCHES
TOL: .XX ± .015, .XXX ± .005, ANGLE ± ½
UNLESS INDICATED OTHERWISE

ALFRED ELECTRONICS
PALO ALTO, CALIFORNIA

SIZE C | 900955 | REV —

SHEET 1 OF 1

ALFRED

Tube Warranty and Replacement Procedure

Tube Replacement

All TWT and BWO tubes furnished in ALFRED instruments are available from ALFRED ELECTRONICS or the tube manufacturer for either warranty or out-of-warranty replacements. Current prices are given on the Replacement Tube Price List.

Tube Warranty

On ALFRED supplied BWO, TWT, and VTM tubes used in catalog instruments, ALFRED ELECTRONICS extends the full warranty given by the tube manufacturer and offers the following minimum:

Warranty for Microwave Associates West, ITT, & Litton TWT's, and Varian-Bomac VTM's

Tubes are warranted unconditionally against defects in workmanship, materials, and construction within the period shown in Column A and the number of heater hours shown in Column B. To supplement the unconditional warranty, the tubes are warranted on a pro-rata basis for the rated number of heater hours shown in Column C or for one year, both computed from the date of original shipment by ALFRED, whichever expires first. The pro-rated adjustment will be based on the current list price of the tube and the unused percentage of heater hours (Column C) or one-year time period, whichever results in lesser credit.

Warranty for MEC TWT's and All BWO Tubes

Tubes are warranted unconditionally against defects in workmanship, materials, and construction within the period shown in Column A and the number of heater hours shown in Column B, both computed from the date of original shipment by ALFRED. The adjustment will be based on the current list price of the tube.

Mfg.	Power	A months	B hours	C hours
		TWT		
MAW	1 - 10 mw	6	500	2000
MEC	1 - 20 mw	12	2000	
MAW	1 watt	6	250	1000
MEC	1 - 10 watt	12	1000	
ITT	10 watt	2	50	500
Litton	10 watt	-	50	500
		BWO		
All	0.5 - 40 GHz	12	2500	
		VTM		
Varian-Bomac	0.25 - 1 GHz	2	100	1000

WARRANTY CONDITIONS APPLY ONLY TO TUBES LISTED ABOVE WHICH ARE USED IN ALFRED CATALOG INSTRUMENTS.

This warranty applies only to tubes sold after June 1, 1968.

Return Authorization

TO OBTAIN WARRANTY CREDIT THE TUBE SERVICE REPORT MUST BE COMPLETED AND RETURNED WITH THE TUBE.

Return Procedure

In case a tube or instrument fails, please contact the factory or your local sales representative for advice or authorization to return either the tube or the instrument to the factory. NO TUBE OR INSTRUMENT WILL BE ACCEPTED FOR REPAIR OR CREDIT ADJUSTMENT WITHOUT WRITTEN AUTHORIZATION AND ACCOMPANYING SERVICE REPORT.

When the authorization is received, pack the tube in a rigid container (use original carton if available) at least 4" larger than the tube in each dimension. Wrap the tube with 1/4" of soft padding material and heavy kraft paper before placing in container. Pack at least 2" of resilient dunnage such as rubberized hair, foam, or similar shock absorbing material completely around the tube. Mark the container "FRAGILE" and ship PREPAID via air freight, air express or rail express. Do not ship via parcel post or air parcel post since experience has shown that fragile items are more apt to be damaged when shipped via these methods.

Use similar wrapping, packing and shipping provisions for an instrument. At least 6" of rubberized hair (or equivalent shock absorbing material) is required for an instrument.

In-Warranty Failure - BWO and VTM Tubes

BWO and VTM tubes which fail in warranty will be replaced with a new tube. In case a tube fails, please issue a purchase order for a new tube at the tube list price and return the defective tube. Warranty credit will be issued and deducted from the price, subject to tube manufacturer's verification that failure was caused by tube malfunction. To qualify for maximum credit, it is essential that the defective tube be properly packed and promptly returned.

Repairable or In-Warranty Failure - TW Tubes

If the returned tube is found to be repairable, the user will be asked to issue a purchase order for repair charges determined by the original tube manufacturer. In general, the repair will be at no cost if the tube is in warranty and there is no evidence of misuse or abnormal conditions of operation.

Warranty Credit

Any applicable credit allowed under the terms of this warranty applies only toward the future purchase of a replacement tube from ALFRED ELECTRONICS. Cash settlements will not be made. In terms of this warranty, a replacement tube must be the same type as that on which credit is allowed. Credit for one tube only may be applied toward the purchase of a single replacement tube. Warranty credit remains in effect for a maximum of six (6) months from date ALFRED ELECTRONICS notifies the customer. All credits will be based on the purchase price of the tube which prevails at the time the order for a replacement tube is received by ALFRED ELECTRONICS.

BWO RF Cables

RF OUTPUT CABLE MUST ACCOMPANY BWO TUBES returned for warranty credit, repair or replacement. If rf output cable is NOT returned, the cable price is added to the normal BWO repair or replacement charge. For prices see Replacement Tube Price List.

Special Conditions

If a returned tube or instrument proves not to be defective after test and evaluation at ALFRED ELECTRONICS, the tube or instrument will be returned at the customer's expense.

The final determination as to whether the tube failed in normal operation thereby bringing it under the applicable warranty or whether the tube was misused thereby excluding it from application of the warranty provisions, lies solely with the tube manufacturer.

Data, warranty credit, and prices subject to change without notice.

6/7/68

ALFRED ELECTRONICS

Service Report

Instrument Model _____ Serial No. _____ Date Received _____

TW/BWO Tube Type _____ Serial No. _____ Date Received _____

Date First Tested _____ Date Placed in Service _____ Date of Failure _____

Total Number of Hours of TWT/BWO Heater Operation _____

_____

1. Was operation normal just prior to failure? Yes _____ No _____

2. If not, what was done to adjust it? _____

_____

_____

3. Has proper cooling been maintained during tube operation? _____

_____

4. Did helix overcurrent tripout occur? _____

_____

5. Was environment normal? (specify) _____

_____

6. Symptoms – (describe failure) _____

_____

_____

7. Operating conditions at time of failure (indicate any unusual conditions) _____

_____

_____

8. Name of person to contact regarding evaluation of failure _____

Telephone No. _____ Signature _____

Title _____

Date _____

ALFRED

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_____

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_____

_____

8. Name of person to contact regarding evaluation of failure _____

Telephone No. _____ Signature _____

Title _____

Date _____

SHIPMENT DAMAGE CLAIM

The instrument should be tested as soon as it is received. If it fails to operate properly or is damaged in any way, a claim must be filed with the carrier. Have carrier agent inspect damage to instrument and packing crate and forward us a copy of his written report. You will then be advised of replacement or repair arrangements and disposition of the equipment. Please include model number, type number and serial number when referring to this instrument for any reason.

WARRANTY

ALFRED products are warranted against defects in workmanship and materials. This warranty is limited to repair or replacement of products or parts (except tubes, transistors, and batteries) which prove defective within one year after delivery to original purchaser. ALFRED ELECTRONICS is not liable for consequential damage.

If any fault develops:

1. Notify us, giving full details of the difficulty, including the model number, type number and serial number. Upon receipt of this information, you will be sent service instructions or shipping data.

2. Upon receipt of shipping instructions, forward the instrument prepaid and repairs will be made at the factory. If requested, an estimate of the charges will be made before the work begins when instrument is not covered by this warranty.

PACKING

The instrument should be packed in the original carton. If unusable or not available, use a wooden box with approximately three inches of excelsior or other shock-absorbing material surrounding the instrument. If desired, packing services of a local transfer and storage company may be employed.

CHAMPION CLASP NO. 55 6x9

MP-77518